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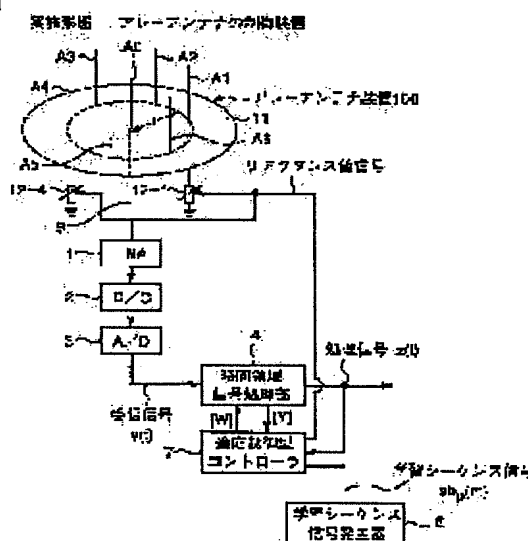
(54) DEVICE AND METHOD FOR CONROLLING ARRAY ANTENNA

(57)Abstract:

PROBLEM TO BE SOLVED: To provide an array antenna controller that has a simple constitution and can be manufactured inexpensively, as compared with the conventional controller and performs temporal and spatial adaptive processing for an ESPAR antenna.

SOLUTION: A time-domain signal processing section 4 divides a signal $y(t)$ received by mean of an array-antenna device 100, composed of the EXPAR antenna into sub-signals in a plurality of time domains, processes the sub-signals in the time domains by respectively multiplying the sub-signals by prescribed weighting factors and adding the weighted sub-signals to each other, and outputs the added signals as processed signal $z(t)$. An adaptable controller 7 computes the weighting factors, based on a learning sequence signal generated from a learning sequence signal generator 6 and the sub-signals, so that the error signals between the sequence signal and processed signals $z(t)$ become minimal, outputs the weighting factors to the time-domain signal processing section 4, and calculates and sets the reactance value of each

variable reactance element, so that the value of a prescribed criterion function, indicating the value corresponding to one of the error signals, becomes minimal by calculating the gradient vector of the criterion function.



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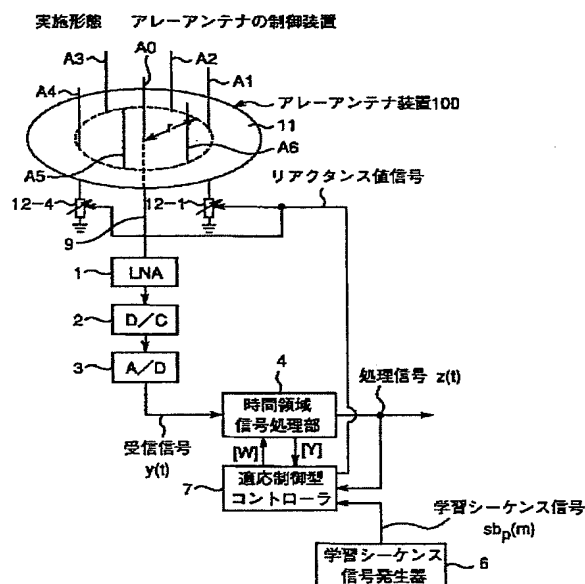
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(54) 【発明の名称】 アレーアンテナの制御装置及び制御方法

(57) 【要約】

【課題】 従来技術に比較して簡単な構成を有しかつ製造コストが安価であり、エスパアンテナのための時空間適応処理を行う。

【解決手段】 時間領域信号処理部4は、エスパアンテナであるアレーアンテナ装置100が受信した信号 $y(t)$ を複数の時間領域のサブ信号に分割し、各サブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号 $z(t)$ として出力する。適応制御型コントローラ7は、学習シーケンス信号発生器6により発生された学習シーケンス信号と上記処理信号 $z(t)$ との誤差信号が最小となるように、学習シーケンス信号と各サブ信号とに基づいて重み係数を演算して時間領域信号処理部4に出力し、誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し基準関数の値が最小となるように各可変リアクタンス素子のリアクタンス値を計算して設定する。



【特許請求の範囲】

【請求項1】 無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御装置において、上記アレーアンテナにおいて受信された無線信号を複数の時間領域のサブ信号に分割し、上記分割した複数のサブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号として出力する時間領域信号処理手段と、所定の学習シーケンス信号と上記各サブ信号とに基づいて、上記処理信号と上記学習シーケンス信号との誤差信号が最小となるように上記重み係数を演算して上記時間領域信号処理手段に出力し、上記誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し、上記基準関数の値が最小となるように上記各可変リアクタンス素子のリアクタンス値を計算して設定する適応型制御手段とを備えたことを特徴とするアレーアンテナの制御装置。

【請求項2】 無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御方法において、上記アレーアンテナにおいて受信された無線信号を複数の時間領域のサブ信号に分割し、上記分割した複数のサブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号として出力するステップと、所定の学習シーケンス信号と上記各サブ信号とに基づいて、上記処理信号と上記学習シーケンス信号との誤差信号が最小となるように上記重み係数を演算して上記時間領域の信号処理のために出力し、上記誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し、上記基準関数の値が最小となるように上記各可変リアクタンス素子のリアクタンス値を計算して設定するステップとを含むことを特徴とするアレーアンテナの制御方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、複数のアンテナ素子からなるアレーアンテナ装置の指向特性を変化させることができるアレーアンテナの制御装置及び制御方法に関し、特に、指向特性を適応的に変化させることができ

る電子制御導波器アレーアンテナ装置 (Electronically Steerable Passive Array Radiator (ESPAR) Antenna; 以下、エスパアンテナという。) であって、TDM A受信信号又はCDMA受信信号を処理可能なアレーアンテナの制御装置及び制御方法に関する。

【0002】

【従来の技術】エスパアンテナは、例えば、従来技術文献1「T. Ohira, "Microwave signal processing and devices for adaptive beamforming," IEEE Antenna and Propagation society International Symposium vol. two, pp. 583-586, Salt Lake City, Utah July 16-21, 2000」や特願平11-194487号の特許出願において提案されている。このエスパアンテナは、無線信号が送受信される励振素子と、この励振素子から所定の間隔だけ離れて設けられ、無線信号が送受信されない少なくとも1個の非励振素子と、この非励振素子に接続された可変リアクタンス素子とから成るアレーアンテナを備え、上記可変リアクタンス素子のリアクタンス値を変化させることにより、上記アレーアンテナの指向特性を変化させることができる。

【0003】また、無線通信には、マルチパス伝搬と、同一チャンネル干渉 (CCI) とが、無線システムに悪影響を及ぼす2つの問題として存在する。これらの問題はそれぞれ、TDMA無線システムにおける周波数の再使用に起因するシンボル間干渉 (ISI) 及び同一チャンネル干渉、又はCDMA無線システムにおけるマルチユーザアクセス干渉 (MAI) として現れる。

【0004】以上の問題点を解決するために、時空間適応型処理 (STAP) (従来技術文献2「J. Paulraj et al., "Space-time processing for wireless communications," IEEE Signal Processing Magazine, Vol. 14, No. 6, pp. 49-83, November 1997」参照。) が提案され、この処理は、ISI及びCCI双方の抑制において卓越した性能を発揮するものと考えられている。最近では、TDMA又は直接拡散 (シーケンス) CDMA (DS-SS-CDMA) 無線通信システムに対して、時空間適応型処理 (STAP) の方法が提案され、解析されている。

【0005】

【発明が解決しようとする課題】しかしながら、STAPシステムのアンテナアレーチャンネルの実現は複雑で高コストであるため、例えば無線構内ネットワークシステム、あるいはユーザ端末機のようにコストが極めて重要な要素であるとされる状況では特に、これらを実際に広く適用することは困難である。これは、構成が簡単であってより低いコストのSTAPシステムを開発することが実質的な重要事項であることを意味している。

【0006】本発明の目的は以上の問題点を解決し、従来技術に比較して簡単な構成を有しかつ製造コストが安価であり、エスパアンテナのための時空間適応処理を行

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うことができるアレーアンテナの制御装置及び制御方法を提供することにある。

【0007】

【課題を解決するための手段】本発明に係るアレーアンテナの制御装置は、無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御装置において、上記アレーアンテナにおいて受信された無線信号を複数の時間領域のサブ信号に分割し、上記分割した複数のサブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号として出力する時間領域信号処理手段と、所定の学習シーケンス信号と上記各サブ信号とに基づいて、上記処理信号と上記学習シーケンス信号との誤差信号が最小となるように上記重み係数を演算して上記時間領域信号処理手段に出力し、上記誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し、上記基準関数の値が最小となるように上記各可変リアクタンス素子のリアクタンス値を計算して設定する適応型制御手段とを備えたことを特徴とする。

【0008】また、本発明に係るアレーアンテナの制御方法は、無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御方法において、上記アレーアンテナにおいて受信された無線信号を複数の時間領域のサブ信号に分割し、上記分割した複数のサブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号として出力するステップと、所定の学習シーケンス信号と上記各サブ信号とに基づいて、上記処理信号と上記学習シーケンス信号との誤差信号が最小となるように上記重み係数を演算して上記時間領域の信号処理のために出力し、上記誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し、上記基準関数の値が最小となるように上記各可変リアクタンス素子のリアクタンス値を計算して設定するステップとを含むことを特徴とする。

【0009】

【発明の実施の形態】従来の適応型アルゴリズムで形成されるヌル、又は信号処理に先立って予め形成される

(formed in advance before) ビームとは異なり、本発

明では、可変なビームパターンと時間領域の等化器とを併用して時空間適応型フィルタリングを実現することができるアレーアンテナの制御装置及び制御方法を提供する。エスパアンテナは、最小コストで所望の信号に向けて空間的にビームを形成する能力を有すると考えられている。本発明では、TDMA又はCDMA信号波形のためにエスパアンテナを使用して時空間適応型フィルタリング(STAF)を実現するためのアレーアンテナの制御装置及び制御方法を提案する。

10 【0010】以下、図面を参照して本発明の実施形態について説明する。

【0011】図1は本発明に係る実施形態のアレーアンテナの制御装置のブロック図である。本実施形態のアレーアンテナの制御装置は、図1に示すように、1つの励振素子A0と6個の非励振素子A1乃至A6とを備える従来技術のエスパアンテナで構成されたアレーアンテナ装置100と、上記アレーアンテナ装置100で受信された無線信号を処理する時間領域信号処理部4と、それらを制御する適応制御型コントローラ7とを備えたことを特徴とする。

20 【0012】図1において、アレーアンテナ装置100は、接地導体11上に設けられた励振素子A0及び非励振素子A1乃至A6から構成され、励振素子A0は、半径rの円周上に設けられた6本の非励振素子A1乃至A6によって囲まれるように配置されている。好ましくは、各非励振素子A1乃至A6は上記半径rの円周上に互いに等間隔を保って設けられる。各励振素子A0及び非励振素子A1乃至A6の長さは、例えば、所望波の波長λの約1/4になるように構成され、また、上記半径rはλ/4になるように構成される。励振素子A0の給電点は同軸ケーブル9を介して低雑音増幅器(LNA)1に接続され、また、非励振素子A1乃至A6はそれぞれ可変リアクタンス素子12-1乃至12-6に接続され、これら可変リアクタンス素子12-1乃至12-6のリアクタンス値は適応制御型コントローラ7からのリアクタンス値信号によって設定される。

40 【0013】図2は、アレーアンテナ装置100の縦断面図である。励振素子A0は接地導体11と電氣的に絶縁され、各非励振素子A0乃至A6は、可変リアクタンス素子12-1乃至12-6を介して、接地導体11に対して高周波的に接地される。可変リアクタンス素子12-1乃至12-6の動作を説明すると、例えば放射素子A0と非励振素子A1乃至A6の長手方向の長さが実質的に同一であるとき、例えば、可変リアクタンス素子12-1がインダクタンス性(L性)を有するときは、可変リアクタンス素子12-1は延長コイルとなり、非励振素子A1乃至A6の電気長が励振素子A0に比較して長くなり、反射器として働く。一方、例えば、可変リアクタンス素子12-1がキャパシタンス性(C性)を有するときは、可変リアクタンス素子12-1は短縮コ

ンデンスとなり、非励振素子A1の電気長が励振素子A0に比較して短くなり、導波器として働く。

【0014】従って、図1のアレーアンテナ装置100において、各非励振素子A1乃至A6に接続された可変リアクタンス素子12-1乃至12-6のリアクタンス値を変化させることにより、アレーアンテナ装置100の平面指向性特性を変化させることができる。

【0015】図1のアレーアンテナの制御装置において、アレーアンテナ装置100は無線信号を受信し、上記受信された信号は同軸ケーブル9を介して低雑音増幅器(LNA)1に入力されて増幅され、次いで、ダウンコンバータ(D/C)2は増幅された信号を所定の中間周波数の信号(IF信号)に低域変換する。さらに、A/D変換器3は低域変換されたアナログ信号をデジタル信号にA/D変換し、A/D変換されたデジタル信号を時間領域信号処理部4に出力する。次いで、時間領域信号処理部4は、アレーアンテナ装置100によって受信された無線信号 $y(t)$ を複数の時間領域のサブ信号に分割し、分割した複数のサブ信号からなる信号ベクトル $[Y]$ を適応制御型コントローラ7に出力し、また、分割された複数のサブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号 $z(t)$ として出力する。そして、適応制御型コントローラ7は、学習シーケンス信号発生器6により発生された学習シーケンス信号から上記処理信号 $z(t)$ を減算して誤差信号を計算し、さらに、適応制御型コントローラ7は、上記学習シーケンス信号及び信号ベクトル $[Y]$ に基づいて誤差信号が最小となるように最適な重み係数ベクトル $[W]$ を演算して時間領域信号処理部4に出力することにより適応制御処理を実行する。ここで、具体的には、適応制御型コントローラ7は、学習シーケンス信号と上記各サブ信号とに基づいて、処理信号 $z(t)$ と学習シーケンス信号との誤差信号が最小となるように上記重み係数を演算して時間領域信号処理部4に出力し、上記誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し、上記基準関数の値が最小となるように各可変リアクタンス素子12-1乃至12-6のリアクタンス値を計算して設定する。

【0016】アレーアンテナ100で受信される無線信号を送信する送信局は、学習シーケンス信号発生器6で発生される所定の学習シーケンス信号と同一の学習シーケンス信号を含む所定のシンボルレートのデジタルデータ信号に従って、無線周波数の搬送波信号を、例えばQPSKなどのデジタル変調法、又は直接拡散スペクトル拡散変調法を用いて変調し、当該変調信号を電力増幅して受信局のアレーアンテナ装置100に向けて送信する。本発明に係る実施形態においては、データ通信を行う前に、送信局から受信局に向けて学習シーケンス信号を含む無線信号が送信され、受信局では、適応制御型

コントローラ7による適応制御処理が実行される。

【0017】次に、図3乃至図5を参照して、図1の時間領域信号処理部4についてより詳細に説明する。図3は、時間領域信号処理部4の第1の実施形態であるTDMA用時間領域信号処理部4-1のブロック図である。TDMA用時間領域信号処理部4-1は、互いに縦続接続された複数($J-1$)個のシフトレジスタ(SR)13-1乃至13-($J-1$)と、複数 J 個のダウンサンプラ14-1乃至14- J と、複数 J 個のトランスバースルフィルタ回路23-1乃至23- J と、加算器17とを備えて構成される。上記シフトレジスタ(SR)13-1乃至13-($J-1$)はそれぞれ、入力されるクロックに基づいて入力信号を1シンボル期間だけ遅延して出力する。トランスバースルフィルタ回路23-1乃至23- J は、重み係数の演算のために、複数の時間遅延のサブ信号に分割された信号データ $Dx1$ 乃至 DxJ を適応制御型コントローラ7に出力し、かつ、適応制御型コントローラ7によって演算された重み係数データ $Dw1$ 乃至 DwJ を、入力された各信号に乗算して出力する。

【0018】図1のA/D変換器3から出力された受信信号 $y(t)$ は、ダウンサンプラ14-1と、シフトレジスタ13-1に入力される。ダウンサンプラ14-1は、入力された受信信号 $y(t)$ を、A/D変換器3のサンプリング周波数の $1/J$ 倍のサンプリング周波数でダウンサンプリングし、処理後の信号を詳細後述するトランスバースルフィルタ回路23-1を介して加算器17に出力する。シフトレジスタ13-1から出力された信号は、ダウンサンプラ14-2と、シフトレジスタ13-2に入力される。ダウンサンプラ14-2は、入力された信号を、A/D変換器3のサンプリング周波数の $1/J$ 倍のサンプリング周波数でダウンサンプリングし、処理後の信号をトランスバースルフィルタ回路23-2を介して加算器17に出力する。以下同様に、シフトレジスタ13- j ($j=2, 3, \dots, J-1$)から出力された信号は、ダウンサンプラ14-($j+1$)と、シフトレジスタ13-($j+1$)に出力される。ダウンサンプラ14-($j+1$)は、入力された信号を、A/D変換器3のサンプリング周波数の $1/J$ 倍のサンプリング周波数でダウンサンプリングし、処理後の信号をトランスバースルフィルタ回路23-($j+1$)を介して加算器17に出力する。さらに、加算器17は、入力された複数 J 個の信号を加算し、加算結果の信号を処理信号 $z(t)$ として出力する。

【0019】図4は、図3のトランスバースルフィルタ回路23-1の構成を示すブロック図である。トランスバースルフィルタ回路23-1は、ダウンサンプラ22-1を通過して入力される信号を、例えば1シンボルの $1/4$ 乃至 $1/2$ の時間だけそれぞれ遅延させ互いに縦続接続された複数($M-1$)個の遅延回路25-1乃至

25-(M-1)と、複数M個の乗算器26-1乃至26-Mと、加算器27とを備えて構成される。トランスバーサルフィルタ回路23-1に入力される信号は、サブ信号のデータとして適応制御型コントローラ7に出力され、かつ、重み係数 $w_{1,1}$ の乗算係数を有する乗算器26-1を介して加算器27に出力されるとともに、互いに縦続接続された(M-1)個の遅延回路25-1乃至25-(M-1)と、重み係数 $w_{1,M}$ の乗算係数を有する乗算器26-Mとを介して加算器27に出力される。ここで、重み係数 w の添え字は、第1の添え字でトランスバーサルフィルタ回路23-1乃至23-Jのシリアル番号1乃至Jを、第2の添え字で上記各トランスバーサルフィルタ回路23-1乃至23-J内の乗算器のシリアル番号1乃至Mを表す。また、遅延回路25-1から出力される信号は、適応制御型コントローラ7に出力されるとともに、重み係数 $w_{1,2}$ の乗算係数を有する乗算器26-2を介して加算器27に出力され、さらに、遅延回路25-2から出力される信号は、適応制御型コントローラ7に出力されるとともに、重み係数 $w_{1,3}$ の乗算係数を有する乗算器26-3を介して加算器17に出力される。以下同様にして、遅延回路26-ma($ma=3, \dots, M-1$)から出力される信号は、適応制御型コントローラ7に出力されるとともに、重み係数 $w_{1,ma+1}$ の乗算係数を有する乗算器26-(ma+1)を介して加算器27に出力される。そして、加算器27は入力されるM個の信号を加算し、加算結果の信号を加算器17に出力する。

【0020】また、図3のトランスバーサルフィルタ回路23-2乃至23-Jは、互いに縦続接続された複数(M-1)個の遅延回路と、複数M個の乗算器と、加算器とを備えて、トランスバーサルフィルタ回路23-1と同様に構成される。時間領域信号処理部4は、各トランスバーサルフィルタ回路23-1乃至23-Jから出力された信号データ $Dx1$ 乃至 DxJ を、信号ベクトル[Y]に合成して適応制御型コントローラ7に出力する。また、時間領域信号処理部4は、適応制御型コントローラ7から入力された重み係数ベクトル[W]を、重み係数データ $Dw1$ 乃至 DwJ に分解して、各トランスバーサルフィルタ回路23-1乃至23-Jにおいてそこに入力された信号と乗算する。

【0021】図5は、図3の第1の実施形態に取って代わる、時間領域信号処理部4の第2の実施形態に係るCDMA用時間領域信号処理部4-2のブロック図である。本実施形態においては、第1の実施形態に係るトランスバーサルフィルタ回路23-1乃至23-Jの代わりに、複数J個のマッチドフィルタ(matched filter; 整合フィルタともいう。)15-1乃至15-Jと、上記各マッチドフィルタ15-1乃至15-Jに接続されたサブ信号処理回路16-1乃至16-Jとを備えたことを特徴とし、それ以外の構成は第1の実施形態のTD

MA用時間領域信号処理部4-1と同様であり、その詳細な説明は省略する。

【0022】図5において、互いに縦続接続されたJ-1個のシフトレジスタ13-1乃至13-(J-1)と、J個のダウンサンプラ14-1乃至14-Jとは、TDMA用時間領域信号処理部4-1と同様に構成される。ダウンサンプラ14-1から出力された信号はマッチドフィルタ15-1に入力され、マッチドフィルタ15-1は、ダウンサンプリングされた信号を、受信機のコントローラ(図示せず。)から入力される所望波のユーザ端末の拡散符号のデータ Dcp に基づいて、白色雑音の中にうずもれた所望波信号を最大のSN比で検出し、具体的には、拡散符号の1周期毎にパルス信号を出力する。次いで、マッチドフィルタ15-1からの信号は、詳細後述するサブ信号処理回路16-1を介して加算器17に出力される。また、ダウンサンプラ14-2から出力された信号は、マッチドフィルタ15-2及びサブ信号処理回路16-2を介して加算器17に出力される。以下同様に、各マッチドフィルタ15-j($j=3, 4, \dots, J$)は、ダウンサンプラ14-faから出力された信号を、サブ信号処理回路16-jを介して加算器17に出力する。

【0023】次いで、図5のサブ信号処理回路16-1の詳細構成について説明する。サブ信号処理回路16-1は、それぞれ所定の遅延時間 Tc を有して縦続接続された複数($Nc-1$)個の遅延回路21-1乃至21-($Nc-1$)と、複数 Nc 個のダウンサンプラ22-1乃至22- Nc と、複数 Nc 個のトランスバーサルフィルタ回路23-1乃至23- Nc と、加算器24とを備えて構成される。マッチドフィルタ15-1から出力された信号は、遅延回路21-1及びダウンサンプラ22-1に出力される。ダウンサンプラ22-1は入力された信号を、ダウンサンプラ14-1乃至14-Jのサンプリング周波数の $1/Nc$ 倍のサンプリング周波数でダウンサンプリングし、処理後の信号をトランスバーサルフィルタ回路23-1を介して加算器24に出力する。

【0024】トランスバーサルフィルタ回路23-1乃至23- Nc は、重み係数の演算のために、複数の時間遅延のサブ信号に分割された信号データ $Dx1$ 乃至 $DxNc$ を適応制御型コントローラ7に出力し、かつ、入力された各信号に、適応制御型コントローラ7によって演算された重み係数のデータ $Dw1$ 乃至 $DwNc$ をそれぞれ乗算する。トランスバーサルフィルタ回路23-1乃至23- Nc の詳細構成は、第1の実施形態に係るTDMA用時間領域信号処理部4-1のトランスバーサルフィルタ回路と同様である(図4参照。)。ここで、乗算される各重み係数 w を区別するために、重み係数 w の添え字は、第1の添え字でサブ信号処理回路16-1乃至16-Jのシリアル番号1乃至Jを、第2の添え字で上記各サブ信号処理回路の中のトランスバーサルフィルタ

回路のシリアル番号1乃至Ncを、第3の添え字で上記各トランスバーサルフィルタ回路の中の乗算器のシリアル番号1乃至Mを表すものとする。

【0025】また、遅延回路21-1から出力された信号は、遅延回路21-2とダウンサンプラ22-2に入力され、ダウンサンプラ22-2は入力された信号を、ダウンサンプラ14-1乃至14-Jのサンプリング周波数の1/Nc倍のサンプリング周波数でダウンサンプリングし、処理後の信号をトランスバーサルフィルタ回路23-2を介して加算器24に出力する。以下同様

に、遅延回路21-nc (nc=2, 3, ..., Nc-1) から出力された信号は、遅延回路21-(nc+1)とダウンサンプラ22-(nc+1)に入力され、ダウンサンプラ22-(nc+1)は入力された信号を、ダウンサンプラ14-1乃至14-Jのサンプリング周波数の1/Nc倍のサンプリング周波数でダウンサンプリングし、処理後の信号をトランスバーサルフィルタ回路23-(nc+1)を介して加算器24に出力する。さらに、加算器24は入力される複数Nc個の信号を加算して加算結果の信号を加算器17に出力する。

【0026】サブ信号処理回路16-2乃至16-Jについても、その内部は、サブ信号処理回路16-1と同様に構成される。加算器17は、サブ信号処理回路16-1乃至16-Jから出力される複数J個の適応制御された信号を加算して、加算結果の信号を処理信号z(t)として出力する。時間領域信号処理部4は、サブ信号処理回路16-1乃至16-J内の複数J×Nc個の各トランスバーサルフィルタ回路23-1乃至23-Ncから出力された信号データDx1乃至DxNcを、信号ベクトル[Y]に合成して適応制御型コントローラ7に出力する。また、時間領域信号処理部4は、適応制御型コントローラ7から入力された重み係数ベクトル[W]を、重み係数データDw1乃至DwNcに分解して、複数J×Nc個の各トランスバーサルフィルタ回路23-2乃至23-Ncにおいてそこに入力された信号と乗算する。

【0027】以上のように構成されたアレーアンテナの制御装置においては、適応制御型コントローラ7は、時間領域信号処理部4から出力される信号ベクトル[Y]と所定の学習シーケンス信号とに基づいて、例えば最小平均2乗誤差(MMSE)基準を用いた所定の適応制御アルゴリズムを用いて、誤差信号が最小となるように複数J×Nc×M個の乗算器26-1乃至26-Mのための各重み係数を演算し、各乗算器26-1乃至26-Mにフィードバックして設定する。

【0028】適応制御型コントローラ7は、さらに、アレーアンテナ装置100の指向性を制御するためのリアクタンス値信号を出力する。ここで、適応制御型コントローラ7は、例えばコンピュータなどのデジタル計算機で構成され、データ通信を開始する前に、時間領域信

号処理部4で発生されたサブ信号と、学習シーケンス信号発生器6で発生された学習シーケンス信号sb

。(m)とに基づいて、図6のフローチャートに図示された適応制御処理を実行することにより上記アレーアンテナ装置100の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子12-1乃至12-6のリアクタンス値X₁, ..., X₆を計算して設定することを特徴としている。具体的には、適応制御型コントローラ7は、各可変リアクタンス素子12-1乃至12-6のリアクタンス値X₁, ..., X₆を順次所定のシフト量ΔXだけ振動させ、各リアクタンス値を変数とする所定の基準関数(本実施形態では、後述する数68における、受信信号y(t)から演算されたサブ信号と上記発生された学習シーケンス信号sb。(m)との関数fh)の勾配ベクトルを計算する。次いで、計算された勾配ベクトルに基づいて当該基準関数値が最大となるようにリアクタンス値X₁, X₂, ..., X₆を計算し、リアクタンス値X₁, X₂, ..., X₆からなるリアクタンス値信号を可変リアクタンス素子12-1乃至12-6に向けて出力し、それによって、上記アレーアンテナ装置100の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるように設定する

【0029】次いで、本発明に係る実施形態のアレーアンテナの制御装置及び制御方法の原理について説明する。

【0030】初めに、P名のユーザ端末を擁するN(N>1)個の素子で構成されるアンテナアレーに到来する信号のモデルについて考察する。送信局から送信された無線信号は、接地導体11を含む平面内で定義される入射角(到来角(Angle of Arrival; AOA)ともいう。)θで入射して、アレーアンテナ装置100で受信される。本実施形態では、励振素子A0を中心として、非励振素子A1の方向をθ=0と定める。送信される信号のp番目のユーザ端末のベースバンド波形信号s_p(t)は、次のように表される。

【0031】

【数1】

$$s_p(t) = \sum_{m=-\infty}^{+\infty} s b_p(m) \rho_p(t-mT)$$

【0032】ここで、sb_p(m)はp番目のユーザ端末の信号に係るm番目の情報シンボルを示し、ρ_p(t)は情報シンボル波形を表す。TDMAシステムでは、情報シンボル波形ρ_p(t)は各ユーザ端末の信号に対して同一であることが多く、スペクトル拡散された余弦変調波形として考えられる。Tは、シンボル持続時間又はシンボル周期を示す。CDMAシステムでは次式が成立し、これをp番目のユーザ端末のパルス波形整形関数と呼ぶ。

【0033】

【数2】

$$\rho_p(t) = \sum_{j=0}^{N_c-1} c_p(j) \Psi(t-jT_c)$$

(0 ≤ t ≤ T)

【0034】ここで、{c_p(j)}、j=0, ..., N_c-1はp番目のユーザ端末に割り当てられた拡散コードであり、Tはチップ間隔T_cとシンボル当たりのチップ数N_cとの積に等しいシンボル継続時間であり、Ψ(t)は時間区間[0, T_c]で定義される正規化されたチップ波形信号である。さらに、オーバーサンプリング周期をΔとすると、T_c/Δ=2であり、伝送ビットレートをf_bとするとシンボルビットレートは2×127×f_bで表される。拡散符号シーケンスは、採用する規格に依存して周期的であっても、非周期的であってもよい。本願明細書では、周期的な場合について考察する。雑音のない、N個のアンテナ素子からなるアレーアンテナ装置で受信された、N次元のアレー受信信号ベクトル[x(t)]は、次のように表される。以下、本願明細書においてベクトル又は行列を[・]で表す。

【0035】

【数3】

$$\begin{aligned} [x(t)] &= \sum_{p=1}^P \sum_{i=1}^{L_p} [a(\theta_i^p)] \xi_i^p s_p(t-\tau_i^p) \\ &= \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) [g_p(t-mT)] \end{aligned}$$

【0036】ここで、数3の中のN次元ベクトル[g_p(t)]を次式のようにp番目のユーザ端末の時空間シンボル波形信号、又はシンボルレベルの時空間チャンネルインパルス応答と呼ぶ。

【0037】

【数4】

$$[g_p(t)] = \sum_{i=1}^{L_p} [a(\theta_i^p)] \xi_i^p \rho_p(t-\tau_i^p)$$

【0038】θ_i^p、τ_i^p、ξ_i^pはそれぞれ、p番目のユーザ端末の信号のi番目の経路に対応する到来角(AOA)、時間遅延及び伝搬損失を表す。さらに、N次元ベクトル[a(θ)]はθに対応するアレーステアリングベクトルを表し、s_p(m)及びL_pはそれぞれ、p番目のユーザ端末の信号に係るm番目の情報シンボル、マルチパス波の総数を示す。数3の成分に対して、以下の事項を仮定している。

<仮定1>受信する信号は、分数間隔(fractionally spaced)のシンボル周期でサンプリングされた場合は広義の周期的な定常状態であり、シンボルレートでサンプリングされた場合は広義の定常状態である。広義の周期的な定常状態の信号ベクトル[x(t)]は、次式で定義される。

【0039】

【数5】E{[x(t₁)] [x(t₂)]^H} = E 50

$$\{[x(t_1+T)] [x(t_2+T)]^H\}$$

【0040】ここで、[・]^Hは共役転置を、E{・}は統計的期待値を示す。

<仮定2>情報シンボルs_p(m)、p=1, 2, ..., Pは独立かつ同一分布であり、かつ次式を満たす。

【0041】

【数6】

E{s_p(m) s_p^{*}(n)} = δ_{m-n}
 【0042】ここで、[・]^{*}は複素共役を、δ_{m-n}はクロネッカーのデルタ関数を示す。

<仮定3>複数のチャンネル{g_p(t)}、p=1, 2, ..., Pは、所定のデータ通信を行う関心を持たれた周期の間は線形かつ時間的に不変であり、時間区間

[0, D_pT]内で有限の持続時間に属する。

【0043】次に、特にアレーアンテナ装置100で受信された信号のモデルについて定式化する。図1が示す励振素子A0及び非励振素子A1乃至A6を備えたアレーアンテナ装置100から出力された、雑音のない受信信号y(t)は、次式で特定される(従来技術文献3

20 「大平孝ほか、"エスバアンテナの等価ウェイトベクトルとアレーファクタ表現式", 電子情報通信学会技術報告, A・P2000-44, SAT2000-41, MW2000-44, 2000年7月」を参照)。

【0044】

$$[\text{数7}] y(t) = [i]^T [x(t)]$$

【0045】また、ステアリングベクトル[a(θ)]は次式で表される。

【0046】

$$[\text{数8}] [a(\theta)] = [1, \exp(j(2\pi r/\lambda) \cos(\theta)), \dots, \exp(j(2\pi r/\lambda) \cos(\theta - 5 \times 2\pi/6))]^T$$

30 【0047】ここで、アレーの直径はr=λ/4であり、λは所望波の無線周波数の波長を表し、従来技術文献3において考察された等価ウェイトベクトル[i]は次式のように導出される。

【0048】

$$[\text{数9}] [i] = C [I + YX]^{-1} [y_0]$$

【0049】ここで、Iは単位行列である。

【0050】

$$[\text{数10}] [y_0] = [y_{00}, y_{10}, y_{10}, y_{10}, y_{10}, y_{10}, y_{10}]^T$$

【数11】

$$X = \begin{bmatrix} R_0 & & & 0 \\ & jX_1 & & \\ & & \ddots & \\ 0 & & & jX_6 \end{bmatrix}$$

【数12】

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$$Y = \begin{bmatrix} y_{00} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} \\ y_{10} & y_{11} & y_{21} & y_{31} & y_{41} & y_{51} & y_{61} \\ y_{10} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} & y_{51} \\ y_{10} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} \\ y_{10} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} \\ y_{10} & y_{51} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} \\ y_{10} & y_{61} & y_{51} & y_{41} & y_{31} & y_{21} & y_{11} \end{bmatrix}$$

【0051】Xはアンテナのパターンを調整するためのリアクタンス行列であり、 $R_0 = 50 \Omega$ は無線受信機の入力インピーダンスであり、 X_1, \dots, X_6 は、適応制御型コントローラ7からリアクタンス値信号として出力されるパラメータである。Yはアンテナの素子間の相互結合を表すアドミタンス行列、 $[y_0]$ は関連したアドミタンスベクトルであって、その成分は以下のものを含む。

【0052】(a) y_{00} は励振素子A0の自己入力アドミタンスを表す。

(b) y_{10} は励振素子A0と非励振素子A1乃至A6との結合アドミタンスを表す。

(c) y_{11} は非励振素子A1乃至A6の自己入力アドミタンスを表す。

*

$$\begin{aligned} y_{00} &= 0.00860035 - 0.0315844j \\ y_{10} &= -0.00372642 + 0.0072319j \\ y_{11} &= 0.00962295 - 0.01656835j \\ y_{21} &= -0.000377459 + 0.0117867j \\ y_{31} &= 0.00002720885 - 0.0063736j \\ y_{41} &= 0.001779525 + 0.002208335j \end{aligned}$$

【0055】数3を数7に代入しかつ相加性雑音を考慮すると、アレーアンテナ装置100の単一ポートから出力された受信信号 $y(t)$ は次式のように表すことができる。

【0056】

【数13】

$$y(t) = [i]^T [x(t)] = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} b_p(m) g_{ap}(t-mT) + n(t)$$

【0057】ここで、数13に含まれた次の関数も、p番目のユーザ端末の時空間シンボル波形信号と呼ばれる。

【0058】

【数14】

$$\begin{aligned} g_{ap}(t) &= [i]^T [g_p(t)] \\ &= \sum_{i=1}^L [i]^T [a(\theta_i^p)] \xi_i^p \rho_p(t - \tau_i^p) \\ &= \sum_{i=1}^L f(\theta_i^p) \xi_i^p \rho_p(t - \tau_i^p) \end{aligned}$$

【0059】ここで、次式で表される $f(\theta)$ はアレー

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* (d) y_{21} は互いに隣接する非励振素子A1とA2、A2とA3、A3とA4、A4とA5、A5とA6、乃至A6とA1の結合アドミタンスを表す。

(e) y_{31} は間に1つの非励振素子をはさんで並ぶ2つの非励振素子A1とA3、A2とA4、A3とA5、A4とA6、A5とA1、乃至A6とA2の結合アドミタンスを表し、

(f) y_{41} は励振素子A0をはさんで対向する2つの非励振素子A1とA4、A2とA5、乃至A3とA6の結合アドミタンスを表す。

【0053】相反性とアレーアンテナ装置100の巡回的な対称性のために、以上のように6つの成分のみが独立である。また、Cはアンテナの利得に関する係数である。図1が示すアレーアンテナ装置100の場合、実際の測定結果から近似的に $C = 131.2$ という値を得ている。表1には、アドミタンスベクトル $[y_0]$ とアドミタンス行列Yへの異なる入力値(エントリ)が示されている。

【0054】

【表1】

*

30 アンテナ装置100のパターンである。

【0060】

【数15】 $f(\theta) = f(\theta, X_1, \dots, X_6) =$ $[i]^T [a(\theta)]$ 【0061】2つの時空間インパルス応答 $g_p(t)$ と $[g_p(t)]$ は、明らかに同じ持続時間を有してい

る。相加性雑音は、以下の仮定を満足している。

<仮定4>相加性雑音は、次の2つの式を満たすゼロ平均の白色雑音であり、ユーザ端末の信号とは無相関である。

【0062】

【数16】 $E\{n^2(t)\} = 0$ 【数17】 $E|n(t)|^2 = \sigma^2$ 【0063】ここで、 σ^2 はノイズのパワーを表す。

【0064】数9乃至数14より、アレーアンテナ装置100の出力信号もリアクタンス X_1, X_2, \dots, X_6 の非線形関数であることが分かる。

【0065】次に、時間領域信号処理部4で実行される、望ましくない信号を除去するための時空間適応型フィルタリングについて説明する。アレーアンテナ装置

50 00の可変リアクタンス素子12-1乃至12-6が、

与えられたリアクタンス値のセットを有するときのアレーアンテナの制御装置の時間的処理を、最初に、図3に図示されたTDMA用時間領域信号処理部4-1を用いて実行する。TDMAの場合は、シンボル波形信号に基づいて処理が行われる。シフトレジスタ13-1乃至13-(J-1)におけるサンプリング周期を Δ で表し、 $J = T/\Delta$ (Jは1以上の整数)をオーバーサンプリング

$$y(i\Delta + mT)$$

$$= \sum_{p=1}^P \sum_{d=0}^{D_p} s_p(m-d) g_{a_p}(i\Delta + dT) + n(i\Delta + mT)$$

$$(i = 0, 1, \dots, J-1)$$

【0067】仮定A1に記述された端末の信号の周期的な定常状態を利用すると(従来技術文献4「L. Tong et al., "Blind identification and equalization based on second-order statistics: a time domain approach," IEEE Transaction. Information Theory, Vol. 40, pp. 340-349, March 1994」参照。)、図3に図示され

$$[y_b(m)] = \sum_{p=1}^P \sum_{d=0}^{D_p} s_p(m-d) [h_p(d)] + [n_b(m)]$$

【0069】ここで、J次元の信号ベクトル $[y_b(t)]$ 、時空間インパルス応答ベクトル $[h_p(d)]$ 、及びノイズベクトル $[n_b(m)]$ は次式で表される。

【0070】

$$[\text{数20}] [y_b(m)] = [y(mT), y(mT-\Delta), \dots, y(mT-(J-1)\Delta)]^T$$

$$[\text{数21}] [h_p(d)] = [g_{a_p}(dT), g_{a_p}(dT-\Delta), \dots, g_{a_p}(dT-(J-1)\Delta)]^T$$

$$[\text{数22}] [n_b(m)] = [n(mT), n(mT-\Delta), \dots, n(mT-(J-1)\Delta)]^T$$

【0071】各mについて受信信号 $[y_b(m)]$ の次元はJであり、Jは「オーバーサンプリングチャンネルの数」と呼ばれる。オーバーサンプリングによる拡張チャンネル数の限界については、従来技術文献5「A. J. van der Veen, "Resolution limits of blind multi-user multi-channel identification scheme - the band-limited case", in Proceeding of ICASSP '96, Atlanta, GA, May 1996」に議論されている。M個のシンボルの周期内の連続サンプルについて、次のJ×M次元信号★

$$[H_p^{(0)}] = \begin{bmatrix} [h_p(0)] & \dots & [h_p(D_p)] & 0 & \dots & \dots & 0 \\ 0 & [h_p(0)] & \dots & [h_p(D_p)] & 0 & \dots & 0 \\ \vdots & \ddots & \dots & \ddots & \dots & \ddots & \vdots \\ 0 & \dots & \dots & 0 & [h_p(0)] & \dots & [h_p(D_p)] \end{bmatrix}$$

【0075】ここで、「0」は、J次元の0ベクトルを表す。数19は次式へと拡張することができる。

【0076】

【数27】

★グの係数とする。受信信号 $y(t)$ を仮定A2により時間 $t = i\Delta + mT$ (ここで、mは任意の整数； $i = 0, 1, \dots, J-1$)でサンプリングすると、数13は次式のようになる。

【0066】

【数18】

※た分数間隔の等化器であるトランスバーサルフィルタ回路23-1乃至23-Jの拡張されたマルチチャンネルモデルの方法は、次式のように容易に確立することができる。

【0068】

【数19】

20★ベクトル $[Y_T(m)]$ と、p番目のユーザ端末の信号に係る $M+D_p$ 個の情報シンボルからなるシンボルベクトル $[S_p(m)]$ と、J×M次元ノイズベクトル $[N(m)]$ とを形成する。

【0072】

$$[\text{数23}] [Y_T(m)] = [y_b(m), y_b(m-1), \dots, y_b(m-M+1)]^T$$

$$[\text{数24}] [S_p(m)] = [s_{b_p}(m), s_{b_p}(m-1), \dots, s_{b_p}(m-M-D_p+1)]^T$$

$$[\text{数25}] [N(m)] = [n_b(m), n_b(m-1), \dots, n_b(m-M+1)]^T$$

30【0073】ユーザ端末pに係る次のシルベスター(Sylvester)たたみ込み行列を、そのチャンネルの $(D_p+1) \times J$ の長さ(次元)のインパルス応答 $[h_p(0)]^T, [h_p(1)]^T, \dots, [h_p(D_p)]^T$ の項で定義すると、次式のような $M \times (M+D_p)$ 次行列になる。

【0074】

【数26】

$$[Y_T(m)] = \sum_{p=1}^P [H_p^{(0)}] [S_p(m)] + [N(m)]$$

【0077】ゆえに、TDMA用時間領域信号処理部4-1におけるサブ信号に対する等化は、次式によって実行することができる。

【0078】

【数28】 $z_T(m) = [W]^T [Y_T(m)]$

【0079】ここで、

【数29】 $[W] = [w_{1,0}, \dots, w_{1,M-1}, \dots, w_{J,0}, \dots, w_{J,M-1}]^T$

は、図4に図示された等化器であるトランスバーサルフィルタ回路23-1のための重み係数ベクトルである。最小平均2乗誤差(MMSE)基準に基づいて、トランスバーサルフィルタ回路23-1のための最適な重み係数は、数30から解かれ、かつ公知のウィナーホッフの解、すなわち数31によって与えられる。

【0080】

【数30】

$$\min_{[W]} E |s_{b_1}(m-v) - z_T(m)|^2$$

【数31】

【 W_{MMSE} 】 $^* = [R_T]^{-1} [r(v)]$

【0081】ここで、 $s_{b_1}(m)$ は所望のユーザ端末の信号の学習シーケンス信号であり、 $v \geq 0$ は、遅延時間 v を考慮した因果的フィルタリング(causal filtering)の実現に必要な学習シーケンス信号の遅延である。数30から明らかなように、適応制御型コントローラ7は、学習シーケンス信号を所定の遅延時間 v だけ遅延した信号 $s_{b_1}(m-v)$ と、処理信号 $z_T(m)$ との誤差が最小となるように重み係数ベクトル $[W]$ を演算す*

$$\begin{aligned} \sigma_{T-MMSE}^2(v) |_{x_{v-1}, x_0} &= E |s_{b_1}(m-v) - z_T(m)|^2 \\ &= E |s_{b_1}(m-v)|^2 - [W_{MMSE}]^T [R_T] [W_{MMSE}]^* \\ &= E |s_{b_1}(m)|^2 - [r(v)]^H [R_T]^{-1} [r(v)] \end{aligned}$$

【0085】実際には、数34の最小残留誤差パワーは、リアクタンス値 X_1, \dots, X_J の関数である。

【0086】アレーアンテナ装置100の可変リアクタンス素子12-1乃至12-6が、与えられたリアクタンス値のセットを有するときのアレーアンテナの制御装置の時間領域処理を、次に、図5に図示されたCDMA用時間領域信号処理部4-2を用いた場合について説明する。CDMAの場合は、当該時間領域処理は、パルス波形整形関数及びそれらの関連したマッチドフィルタ1※

$$\begin{aligned} y(1aTc - i\Delta) \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_{b_p}(m) g_{a_p}(1aTc - i\Delta - mT) + n(1aTc - i\Delta) \end{aligned}$$

【0088】離散化された受信信号 $y(1aTc - i\Delta)$ 、 $i = 0, \dots, J-1$ を積み重ねると、次式のよう
な信号ベクトルが得られる。★

$$\begin{aligned} [y_v(1aTc)] \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_{b_p}(m) [g_{v_p}(1aTc - mT)] + [n_v(1aTc)] \end{aligned}$$

【0090】ここで、 $[y_v(1aTc)]$ 、 $[g_{v_p}(1aTc)]$ 、 $[n_v(1aTc)]$ によって、それぞれ以下のように、信号ベクトル、時空間シンボル波形

*ることにより適応制御する。 $[R_T]$ 及び $[r(v)]$ はそれぞれ、以下のように演算される、信号ベクトルの時間的相関行列と、学習シーケンス信号と信号ベクトルの間の相関ベクトルである。

【0082】

【数32】 $[R_T] = E \{ [Y_T(m)] [Y_T(m)]^H \}$ 【数33】 $[r(v)] = E \{ s_{b_1}^*(m-v) [Y_T(m)] \}$

【0083】適応制御型コントローラ7は、数31乃至33によって求められた重み係数ベクトル $[W]$ を時間領域信号処理部4に出力し、重み係数ベクトル $[W]$ は、複数 $J \times M$ 個の乗算器26-1乃至26-Mにおいて信号ベクトル $[Y_T]$ と乗算され、乗算結果の信号が加算器27及び17で加算されて出力される。出力された信号 $z_T(k)$ と学習シーケンス信号との誤差信号に基づいて、適応制御型コントローラ7は上述の処理を繰り返して数30の誤差を収束させることにより、出力信号 $z_T(k)$ の残留誤差パワーを最小化させる。また、アレーアンテナ装置100の可変リアクタンス素子12-1乃至12-6が、与えられたリアクタンス値のセットを有するときの最小の残留誤差パワーは、次式のように求められる。

【0084】

【数34】

30※5-1乃至15-Jからの出力信号に対して行われる。シフトレジスタ13-1乃至13-(J-1)におけるサンプリング周期を $\Delta = Tc/J$ で示し(Jは自然数であるオーバーサンプリング係数)、受信信号 $y(t)$ を時間 $t = 1aTc - i\Delta$ 、(1aは自然数; $i = 0, 1, \dots, J-1$)でサンプリングすると、数13の離散形式は、次式のようになる。

【0087】

【数35】

★【0089】

【数36】

信号、及びノイズを示すJ次元ベクトルを意味する。

【0091】

【数37】 $[y_v(1aTc)] = [y(1aTc)]$

..., $y(1aTc - (J-1)\Delta)]^T$

【数38】 $[g v_p(1aTc)] = [g a_p(1aTc), \dots, g a_p(1aTc - (J-1)\Delta)]^T$

【数39】 $[n v(1aTc)] = [n(1aTc), \dots, n(1aTc - (J-1)\Delta)]^T$

【0092】正規化されたチップ波形について、次式を仮定する。

【0093】

【数40】 $\Psi(kTc - 1aTc) = \delta_k$

【0094】このとき、 p 番目のユーザ端末の離散的なパルス波形整形関数は、次式で示される。

【0095】

【数41】

$$\begin{aligned} \rho_p(1aTc) &= \sum_{j=0}^{Nc-1} c_p(j) \Psi(1aTc - jTc) \\ &= \sum_{j=0}^{Nc-1} c_p(j) \delta_{1aj} \\ &= c_p(1a) \end{aligned}$$

*

$Xb(1aTc)$

$$= \sum_{i=0}^{Nc-1} [y v(1aTc - iTc)] \rho_{p_0}(NcTc - iTc)$$

$$= \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s b_p(m) [q v_p^{(p_0)}(1aTc - mT)] + [X b_n^{(p_0)}(1aTc)]$$

【0098】ここで、

※ ※ 【数44】

$$[q v_p^{(p_0)}(1aTc)] = \sum_{i=0}^{Nc-1} [g v_p(1aTc - iTc)] c v_{p_0}(i)$$

【数45】

$$[X b_n^{(p_0)}(1aTc)] = \sum_{i=0}^{Nc-1} [n v(1aTc - iTc)] c b_{p_0}(i)$$

【0099】数19のベクトルの定式化と同様に、 $1aTc$ を $kT - jTc$ （ここで、 $0 \leq j \leq Nc-1$ ）で表し、サブ信号処理回路16-1乃至16- Nc 内におけるシンボルレベルの信号ベクトルを次式のように定義する。

【0100】

$[Xc(kT)]$

$$= \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s b_p(m) [q c_p^{(p_0)}(kT - mT)] + [X c_n^{(p_0)}(kT)]$$

【0103】ここで、

☆ ☆ 【数48】

$[q c_p^{(p_0)}(kT)]$

$$= [[q v_p^{(p_0)}(kT)]^T, \dots, [q v_p^{(p_0)}(kT - (Nc-1)Tc)]^T]^T$$

【数49】

$[X c_n^{(p_0)}(kT)]$

$$= [[X b_n^{(p_0)}(kT)]^T, \dots, [X b_n^{(p_0)}(kT - (Nc-1)Tc)]^T]^T$$

【0104】仮定3より、 $J \times Nc$ 次元の波形信号

$$[q c_p^{(p_0)}(kT)]$$

【数50】

の持続時間が制限されていることが知られている。ゆえ * 【0105】
に、数47は次式のように表すことができる。 * 【数51】

$$[X_c(kT)] = \sum_{d=0}^{D_0} s_{p_0}(k-d) [q_{c_{p_0}}(dT)] \\ + \sum_{p=p_0}^P \sum_{d=0}^{D_p} s_p(k-d) [q_{c_p}(dT)] + [X_{c_n}(kT)]$$

【0106】ここで、
【数52】

$$D_{p_0}$$

は、 p_0 番目のユーザ端末チャンネルのシンボルレベルの長さである。数51は、右辺の第1項が所望のユーザ端末からの信号の全成分を包含しているのに対して、第2項は望ましくないユーザ端末からの信号の重ね合わせ※

$$z_c(k) = \sum_{b=0}^{M-1} [w_b]^T [X_c((k-1)bT)] = [W]^T [Y_c(k)]$$

【0108】ここで、 $J \times N_c \times M$ 次元の信号ベクトル $[Y_c(k)]$ と、重み係数ベクトル $[W]$ は次式で表される。

【0109】

$$[\text{数54}] [Y_c(k)] = [[X_c(kT)]^T, \dots, [X_c(kT - (M-1)T)]^T]^T$$

【0110】

【数55】

$$[W] = [[w_0]^T, \dots, [w_{M-1}]^T]$$

$$[\text{数56}] [w_{m,a}] = [w_{1,1,m,a}, w_{2,1,m,a}, \dots, w_{J,1,m,a}, w_{1,2,m,a}, w_{2,2,m,a}, \dots, w_{J,2,m,a}, \dots, w_{1,N_c,m,a}, w_{2,N_c,m,a}, \dots, w_{J,N_c,m,a}]^T$$

$$[w_{1,1,m,a}, w_{2,1,m,a}, \dots, w_{J,1,m,a}, w_{1,2,m,a}, w_{2,2,m,a}, \dots, w_{J,2,m,a}, \dots, w_{1,N_c,m,a}, w_{2,N_c,m,a}, \dots, w_{J,N_c,m,a}]^T$$

($m=1, 2, \dots, M$)

【0111】数56は、信号ベクトル $[Y_c(kT)]$ に乗算される重み係数であり、その全ての重み係数から、数55の重み係数ベクトル $[W]$ が生成される。トランスバーサルフィルタ回路23-1乃至23- N_c のタップ数 M は、 p_0 番目のユーザ端末チャンネルのシンボルレベルの長さ

$$[\gamma_{p_0}(v)] = E \{ s_{b_{p_0}}^*(k-v) [Y_c(k)] \}$$

【0115】ここで、
【数62】

$$s_{b_{p_0}}(k)$$

は p_0 番目のユーザ端末の学習シーケンス信号(学習シンボルシーケンス)を示す。数58から明らかなように、適応制御型コントローラ7は、学習シーケンス信号を所定の遅延時間 v だけ遅延した信号 $s_{b_{p_0}}(k-v)$ と、処理信号 $z_c(k)$ との誤差が最小化され、アンテナの制御装置が最良の性能を出力するように重み係数ベクトル $[W]$ を演算することにより適応制御

※れた相互相関成分を含んでいることを示している。上記相互相関成分は抑圧されなければならない。数51に基づいて、シンボルレベルの適応型処理は次式のように実行することができる。

【0107】

【数53】

★【数57】

$$D_{p_0}$$

と、同一チャンネルのユーザ端末数と、性能要件とに従って選択される。TDMAの場合の処理と同様に、MMSE基準、すなわち、数58に基づいて、最適な重み係数ベクトルが数59のように取得される。

【0112】

【数58】

$$\min_{[W]} E |s_{b_{p_0}}(k-v) - z_c(k)|^2$$

【数59】

$$[W_{p_0}]^* = [R_c]^{-1} [\gamma_{p_0}(v)]$$

30 【0113】ここで、信号ベクトルの時間的相関行列 $[R_c]$ と、学習シーケンス信号と信号ベクトルとの相関ベクトル $[\gamma_{p_0}(v)]$ とはそれぞれ次式で表される。

【0114】

【数60】

$$[R_c] = E \{ [Y_c(k)] [Y_c(k)]^H \}$$

★【数61】

40 する。適応制御型コントローラ7は、数59乃至61によって求められた重み係数ベクトル $[W]$ を時間領域信号処理部4に出力し、重み係数ベクトル $[W]$ は、 $J \times N_c$ 個のトランスバーサルフィルタ回路23-1乃至23- N_c において信号ベクトル $[Y_c]$ と乗算され、乗算結果の信号が加算器24において加算されてサブ信号処理回路16-1乃至16- N_c から出力される。出力される処理信号 $z(k)$ と学習シーケンス信号との誤差信号に基づいて、適応制御型コントローラ7は上述の処理を繰り返して収束させることにより、出力される処理信号 $z(k)$ の残留誤差パワーを最小化させる。数34

と同様に、アレーアンテナ装置100の可変リアクタンス素子12-1乃至12-6が与えられたリアクタンス値のセットを有するときの最小残留誤差パワーは、次式*

$$\begin{aligned}\sigma_{\text{C_MMS}}^2(v) \mid_{x_1, \dots, x_p} &= E \left| s b_p(k-v) - z_c(m) \right|^2 \\ &= E \left| s b_p(k-v) \right|^2 - [W_p]^T [R_c] [W_p]^* \\ &= E \left| s b_p(k) \right|^2 - [\gamma_p(v)]^H [R_c]^{-1} [\gamma_p(v)]\end{aligned}$$

【0117】適応制御型コントローラ7は、以上説明したように、時間領域信号処理部4において所望信号を時間領域において適応処理すると同時に、アレーアンテナ装置100において所望信号を空間領域において処理することができる（時空間併用適応型フィルタリング）。上記の内容から、アレーアンテナ装置100の可変リアクタンス素子12-1乃至12-6が所定のリアクタンス値のセットを有するときは、TDMAの場合もCDMAの場合も共に処理の定式化が同一の方法に包含され得ることが分かる。以下、処理信号 $z(m)$ は、TDMA及びCDMA双方の場合の処理出力を表し、これは次式で表される。

【0118】

$$\text{【数64】 } z(m) = [W]^T [Y(m)]$$

【0119】上述のように、信号ベクトル $[Y(m)]$ は、また、可変リアクタンス素子12-1乃至12-6のリアクタンス値の関数であり、 p 番目のユーザ端末の信号に対する最適な時空間の処理を併用する適応型フィルタリングは、重み係数ベクトル $[W]$ 及びリアクタンス値 X_1, X_2, \dots, X_p を同時に参照して数65を最小化すること、すなわち、数66のように表記される。

【0120】

【数65】

$$\sigma_{\text{t a s}}^2 = E \left| s b_p(m-v) - z(m) \right|^2$$

【数66】

$$(X_{h_1}, \dots, X_{h_p}, W_h)_{o,p,t}$$

$$= \arg \min_{x_1, \dots, x_p, [W]} E \left| s b_p(m-v) - [W]^T [Y(m)] \right|^2$$

【0121】与えられたデータのセットの下では、数6※

$$(X_{h_1}, \dots, X_{h_p})_{o,p,t}$$

$$= \arg \min_{x_1, \dots, x_p} E \left| s b_p(m-v) - [W_{o,p,t}]^T [Y(m)] \right|^2$$

$$= \arg \min_{x_1, \dots, x_p} \left\{ E \left| s b_p(m) \right|^2 - [r(v)]^H [R]^{-1} [r(v)] \right\}$$

$$= \arg \min_{x_1, \dots, x_p} \left\{ \sigma_p^2 - [r(v)]^H [R]^{-1} [r(v)] \right\}$$

【0125】ここで、

$$\text{【数68】 } [W_{o,p,t}]^* = [R]^{-1} [r(v)]$$

$$\text{【数69】 } [R] = E \{ [Y(m)] [Y(m)]^H \}$$

【数70】

$$[r(v)] = E \{ s b_p^* (m-v) [Y(m)] \}$$

【0126】学習シーケンス信号の遅延時間 v は、数30及び数58の基準に基づいて、時間 v だけ遅延された

※のように表される。

$$\text{【0116】}$$

$$\text{【数63】}$$

※6の最適な重み係数ベクトル及びリアクタンス値の解法は、関連付けられたフィールド上での大域的な検索の実行であることが知られている。しかしながら、こうした時間のかかる大域的な検索を実際に使用することは不可能である。よって、何らかの代替方法を考える必要がある。

【0122】最適化方法の中でも最も基本的な方法は、座標に基づいた択一検索法(alternative search)であり、多くの用途に首尾良く適用されている。本願明細書では、この座標に基づいた択一検索法を使用して数66の最適化問題を解く。

【0123】次いで、上記時空間併用適応型フィルタリングを実際に行うためのブロック更新アルゴリズムについて説明する。以上の説明においては、可変リアクタンス素子12-1乃至12-6のリアクタンス値が予め与えられた値を有すると仮定して、重み係数ベクトル $[W]$ を計算する手順が説明された。本願明細書の以下の部分では、図6のフローチャートに基づいて、適応制御型コントローラ4によって実行される、アレーアンテナ装置100のリアクタンス値の適応制御処理について説明する。座標に基づく択一検索の点において、数66の最適化問題を、視点の異なる2つの段階の手順から定式化する。まず、一般的な手順の説明として、リアクタンス値 X_1, X_2, \dots, X_p が固定されていると仮定し、最適な重み係数ベクトルを解く。これは、数31又は数59に示されている。従って、数66は、次式のようになる。

【0124】

【数67】

学習シーケンス信号と処理信号 $z(t)$ との誤差が最小化されるように、適応制御型コントローラ7によって予め決定されている。また次式は、 p 番目のユーザ端末のシンボル信号のパワーである。

【0127】

$$\text{【数71】 } \sigma_p^2 = E \left| s b_p(m) \right|^2$$

【0128】次いで、最適化問題を解くブロック更新の

手順をより具体的に説明する。受信データの制限された長さで数67に従って最適なリアクタンス値を探し、それによって信号ベクトルの時間的相関行列[R]と、学習シーケンス信号と信号ベクトルとの相関ベクトル[r(v)]とを推定する。すなわち、次の2つの演算を実行する。

$$[r_h(v)] = \frac{1}{N_t} \sum_{m=m_k}^{m_k+N_t-1} s_b^*(m-v) [Y(m)] \quad |_{x_1, \dots, x_6}$$

【0130】ここで、 $m_k = N_t \cdot l$, $l = 0, 1, \dots, M_t$ であり、 M_t は収束に必要なデータブロック数を示す。シンボル数 N_t は、与えられたリアクタンス値のセットの下では、最小平均2乗(LMS)アルゴリズムの使用によって、重み係数ベクトル[W]が N_t 個のシンボル周期内で定常状態に収束できるように選択される。数7、数9、数13、数26、数54及びこれらに関連する等式により、信号ベクトル[Y(m)]はリアクタンス値 X_1, X_2, \dots, X_6 が陽に表現された関数ではないことが分かる。つまり、相関ベクトルの2次形式の項 $[r(v)]^H [R]^{-1} [r(v)]$ はリアクタンス値 X_1, X_2, \dots, X_6 の陰関数であることを意味する。

【0131】陰関数に対して、最適なリアクタンス($X_{h1}, X_{h2}, \dots, X_{h6}$)を s_b を発見するために適当な更新アルゴリズムは、リアクタンスを更新するための最急降下アルゴリズムであり、リアクタンス値 X_1, X_2, \dots, X_6 に関する項 $[r(v)]^H [R]^{-1} [r(v)]$ の勾配ベクトルが評価されなければならない。項 $[r(v)]^H [R]^{-1} [r(v)]$ は、※

$$\nabla_{Xv} f_h(Xv) = \nabla_{Xv} f_h(Xv^{(k)}) - \alpha \nabla_{Xv} f_h(Xv) \quad |_{Xv=Xv^{(k)}}$$

【0135】ここで、

$$[数76] Xv = [X_1, X_2, \dots, X_6]^T$$

$$[数77] Xv^{(k)} = [X_1^{(k)}, X_2^{(k)}, \dots, X_6^{(k)}]^T$$

$$\nabla_{Xv} f_h(Xv) = [\nabla_{X_1} f_h(X_1, \dots, X_6), \dots, \nabla_{X_6} f_h(X_1, \dots, X_6)]^T$$

【数79】

$$\nabla_{X_1} f_h(X_1, \dots, X_6)$$

$$\approx [f_h(X_1, \dots, X_6 + \Delta X, \dots, X_6) - f_h(X_1, \dots, X_6, \dots, X_6)] / \Delta X$$

【0137】ここで、 α は更新のためのステップサイズであり、例えば1000乃至2000の値を取る。

【0138】図6に図示された適応制御処理によるリアクタンス値の更新の手順は以下のように実行される。ステップS1において、リアクタンス値更新の反復回数を制御する数 ϵ を設定し、さらに、初期状態としてリアクタンスの更新回数 k を0に定める。次に、ステップS2において、リアクタンス値ベクトルの初期値 $Xv^{(0)} = (X_1^{(0)}, X_2^{(0)}, \dots, X_6^{(0)})$ を設定し、次いで、ステップS3において、リアクタンス値ベクトル $Xv^{(k)}$ に対応するリアクタンス値信号を発生

*【0129】

【数72】

$$[Rh] = \frac{1}{N_t} \sum_{m=m_k}^{m_k+N_t-1} [Y(m)] [Y(m)]^H \quad |_{x_1, \dots, x_6}$$

【数73】

※長さの限定された、与えられたデータブロックに従って評価されるため、ブロック更新アルゴリズムは、項 $[r(v)]^H [R]^{-1} [r(v)]$ のデータブロックに基づく推定値に関して構成される。次式を基準関数として仮定する。

【0132】

【数74】

$$[f_h(X_1, X_2, \dots, X_6)]$$

$$= \sigma h_p^2 - [r_h(v)]^H [Rh]^{-1} [r_h(v)] \quad |_{x_1, \dots, x_6}$$

【0133】ここで、右辺の第2項はリアクタンス値 X_1, \dots, X_6 を変数とする。 σh_p^2 は p 番目のユーザ端末のシンボル信号の評価されたパワーである。最急降下アルゴリズム(従来技術文献6「R. A. Monzingo et al., "Introduction to Adaptive Arrays", John Wiley & Sons, Inc., 1980」を参照)の文脈においては、数74より、リアクタンス値に対して適応制御処理を実行するための、次のような更新方程式が得られる。

【0134】

【数75】

$$★ \dots, X_6^{(k)}]^T$$

【0136】

【数78】

40 して、可変リアクタンス素子12-1乃至12-6に出力して設定する。例えば、リアクタンス値ベクトルの初期値を0ベクトルに設定し、全方向性のビームパターン(図9を参照)から更新アルゴリズムを開始することができる。そして、ステップS4において、受信信号ベクトル[Y(m)]及び学習シーケンス信号ベクトル $s_b(m)$ に基づいて、数72及び数73を用いて、相関行列[R]及び相関ベクトル[r(v)]を計算し、数68を用いて最適な重みベクトル $[W_{opt}]$ を計算して時間領域信号処理部4に出力する。次いで、ステップS5において、数78及び数79を用いて基準関数 f_h

の勾配を計算し、さらに、数75によってリアクタンス値ベクトル $Xv^{(k)}$ からリアクタンス値ベクトル $Xv^{(k+1)}$ を計算する。次いで、ステップS6において、次式の不等式が成立するか否かを決定する。

【0139】

【数80】

$$|fh(Xv^{(k)}) - fh(Xv^{(k+1)})| \leq \varepsilon$$

【0140】ここで、 ε は反復しきい値であり、ステップS6において数80の不等式が成立するときはステップS8に進む一方、成立しないとき(NO)はステップS7に進み、kを1だけインクリメントしてステップS3に戻る。ステップS8において、リアクタンス値ベクトル $Xv^{(k+1)}$ に対応するリアクタンス値信号を発生して、可変リアクタンス素子12-1乃至12-6に出力して設定し、適応制御処理を終了する。

【0141】以上説明したエスバアンテナに基づいた時空間適応型フィルタリングを用いれば、所望信号の到来方向にアレーアンテナ装置100のビームをステアリングして空間的な干渉を抑圧し、時間領域信号処理部4によって受信信号の中に含まれるISI等の時間的な干渉を抑圧することができる。

【0142】

【実施例】本発明者らは、図1のアレーアンテナの制御*

*装置についてコンピュータシミュレーションを実行し、このアレーアンテナの制御装置を用いることによる時空間適応型フィルタリングの有効性を確かめた。このシミュレーションでは、構内ネットワークシステムであって、15個の同一チャンネルのDS-CDMAユーザ端末の信号が存在し、ユーザ1を所望ユーザとする。全てのユーザ端末の信号のコード長さは、127に設定する。各ユーザ端末の信号は6つのマルチパス波を有し、角度が互いに8度の間隔を有するように設定された各ユーザ端末の信号の経路のAOAはガウス分布し、かつそれらの時間遅延は1.1シンボル周期で広がった遅延を有する指数分布に従うものと仮定する。マルチパス波の伝搬損失は、ユーザ端末の信号の直接波のアレー素子のSNRに包含されるものとする。この場合は、ユーザ1の端末の信号に対するSNRが-10dBと仮定されており、他の全てのユーザ端末の信号のSNRは-26.55dB乃至-4.76dBでランダムに変化する。また全てのユーザ端末は、アレーアンテナ装置100の視野内に一様に分布しているものとする。表2は、ユーザ1の端末の信号の詳細なパラメータを記載している。

【0143】

【表2】

経路	θ (度)	τ (シンボル)	ε (伝搬損失)
1	12.30	0	$-0.9669 + 0.2550j$
2	21.50	0.04	$0.7437 - 0.3081j$
3	20.20	0.05	$-0.5206 - 0.5100j$
4	8.70	0.12	$-0.3081 - 0.4569j$
5	23.40	0.33	$-0.1806 + 0.3931j$
6	13.20	0.47	$-0.1912 + 0.1275j$

【0144】ここでは、オーバーサンプリング係数を $J=1$ と設定し、またトランスバーサルフィルタ回路のタップ数を $M=1$ と設定している。上述したように、例えば、可変リアクタンス素子12-1乃至12-6が、

【数81】 $Xv = [-53, -136, 61, 51, 59, -146]^T$

のような与えられたリアクタンス値のセットを有する場合、 N_s はシンボルレベルのサンプル数であり、これに基づいて数64の重み係数ベクトルは従来のLMSアルゴリズムによって数68のその定常状態へと収束することができる。

【0145】図7は図6の適応制御処理において、定常状態に収束するシンボルレベルのサンプル数 N_s を決定するための残留誤差パワーの収束曲線の一例を表すグラフである。図7から明らかなように、重み係数ベクトルは約200のシンボル周期内でその定常状態へと収束することが分かる。これは、シンボル周期の数 $N_s = 20$

0を採用できることを意味している。このシミュレーションのリアクタンスの反復では、シンボル周期の数として $N_t = 200$ を採用している。更新アルゴリズムの収束の際の挙動を示すため、データブロック数 $M_t = 7 \times 20$ と、数81のための反復しきい値 $\varepsilon = 1 \times 10^{-10}$ を設定する。

【0146】図8は、図6の適応制御処理において、データブロック更新のための基準関数値の収束曲線の一例を示すグラフであり、図9は、図6の適応制御処理を実行したときの、リアクタンス値ベクトルの初期値 $Xv^{(0)} = (0, 0, 0, 0, 0, 0)$ に対応するアレーアンテナ装置100のビームパターンのグラフである。このリアクタンス値ベクトルの初期値 $Xv^{(0)}$ から開始して図6の適応制御処理を実行して更新し、更新の回数kがそれぞれ、2回、4回、9回、13回、19回のときのビームパターンを図10乃至図14に示す。表2及び図14から明らかなように、所望のユーザ端末の信

号の全てのマルチパス波は定常状態パターンによって包含されかつ強化され、望ましくないユーザ端末の信号のマルチパス波は定常状態パターンの低位ローブによって軽減されることが分かる。この2つの図面から、アレーアンテナ装置100のビームパターン形成と時間領域信号処理部における受信信号の時間的な等化とを併せて実施することにより、時空間適応型フィルタリングを効果的に実現できることは明らかである。

【0147】

【発明の効果】以上詳述したように本発明によれば、エ 10
スパアンテナにおいて受信された無線信号を複数の時間領域のサブ信号に分割し、上記分割した複数のサブ信号に対してそれぞれ所定の重み係数を乗算した後加算することにより時間領域の信号処理を実行して処理信号として出力し、所定の学習シーケンス信号と上記各サブ信号とに基づいて、上記処理信号と上記学習シーケンス信号との誤差信号が最小となるように上記重み係数を演算して上記時間領域信号処理手段に出力し、上記誤差信号に対応する値を示す所定の基準関数の勾配ベクトルを計算し、上記基準関数の値が最小となるように上記各可変リアクタンス素子のリアクタンス値を計算して設定するように構成した。従って、従来技術に比較して簡単な構成を有しかつ製造コストが安価であり、エスパアンテナのための時空間適応処理を行うことができる。また、同一チャンネル干渉信号を適応的なビームパターン形成によって空間的に有効的に抑制することができ、また、シンボル間干渉信号は時間的な波形に基づく適応型等化によって有効的に抑制することができる。

【図面の簡単な説明】

【図1】 本発明に係る実施形態のアレーアンテナの制 30
御装置の構成を示すブロック図である。

【図2】 図1のアレーアンテナ装置100の断面図である。

【図3】 図1の時間領域信号処理部4の第1の実施形態であって、TDMA用時間領域信号処理部4-1の構成を示すブロック図である。

【図4】 図3のトランスバーサルフィルタ回路23-1の構成を示すブロック図である。

【図5】 図1の時間領域信号処理部4の第2の実施形態であって、CDMA用時間領域信号処理部4-2の構成を示すブロック図である。 40

【図6】 図1の適応制御型コントローラ7によって実行される適応制御処理を説明するフローチャートである。

【図7】 図6の適応制御処理において、定常状態に収束するシンボルレベルのサンプル数 N_s を決定するための残留誤差パワーの収束曲線の一例を表すグラフである。

【図8】 図6の適応制御処理において、データブロック更新のための基準関数値の収束曲線の一例を示すグラフである。

【図9】 図6の適応制御処理を実行したときの、リアクタンス値ベクトルの初期値 $X_v^{(0)} = (0, 0, 0, 0, 0, 0)$ に対応するアレーアンテナ装置100のビームパターンのグラフである。

【図10】 図6の適応制御処理を実行し、リアクタンス値の更新回数が2回であるときのアレーアンテナ装置100のビームパターンのグラフである。

【図11】 図6の適応制御処理を実行し、リアクタンス値の更新回数が4回であるときのアレーアンテナ装置100のビームパターンのグラフである。

【図12】 図6の適応制御処理を実行し、リアクタンス値の更新回数が9回であるときのアレーアンテナ装置100のビームパターンのグラフである。

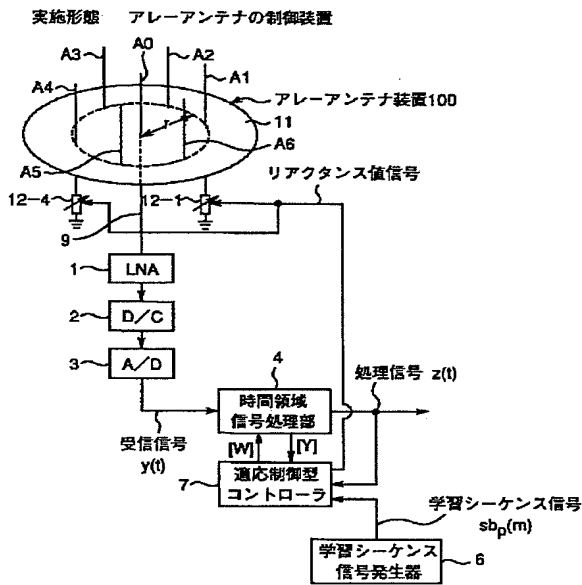
【図13】 図6の適応制御処理を実行し、リアクタンス値の更新回数が13回であるときのアレーアンテナ装置100のビームパターンのグラフである。

20 【図14】 図6の適応制御処理を実行し、リアクタンス値の更新回数が19回であるときのアレーアンテナ装置100のビームパターンのグラフである。

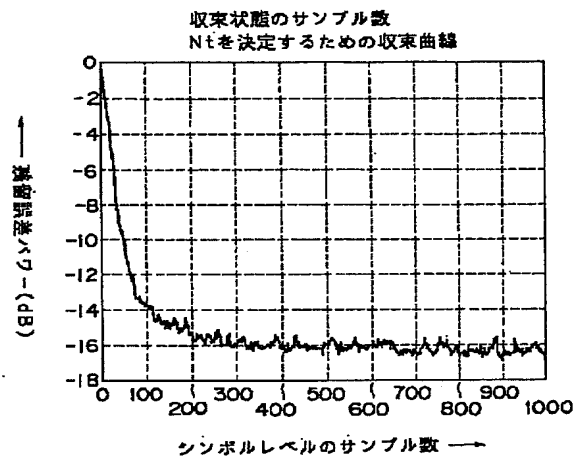
【符号の説明】

A0…励振素子、
A1乃至A6…非励振素子、
1…低雑音増幅器、
2…ダウンコンバータ、
3…A/D変換器、
4…時間領域信号処理部、
4-1…TDMA用時間領域信号処理部、
4-2…CDMA用時間領域信号処理部、
6…学習シーケンス信号発生器、
7…適応制御型コントローラ、
9…同軸ケーブル、
11…接地導体、
12-1乃至12-6…可変リアクタンス素子、
13-1乃至13-(J-1)…シフトレジスタ、
14-1乃至14-J, 22-1乃至22-Nc…ダウンサンブラ、
15-1乃至15-J…マッチドフィルタ、
16-1乃至16-J…サブ信号処理回路、
17, 24, 27…加算器、
23-1乃至23-J, 23-1乃至23-Nc…トランスバーサルフィルタ回路、
21-1乃至21-(Nc-1), 25-1乃至25-(M-1)…遅延回路、
26-1乃至26-M…乗算器、
100…アレーアンテナ装置。

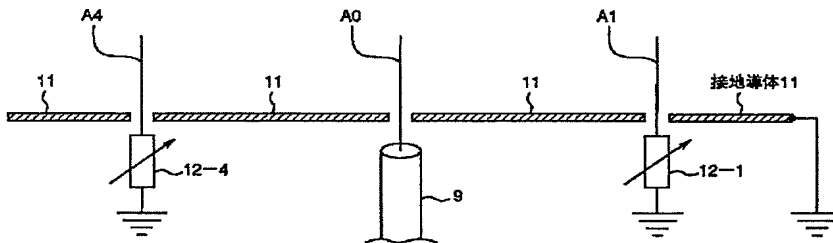
【図1】



【図7】

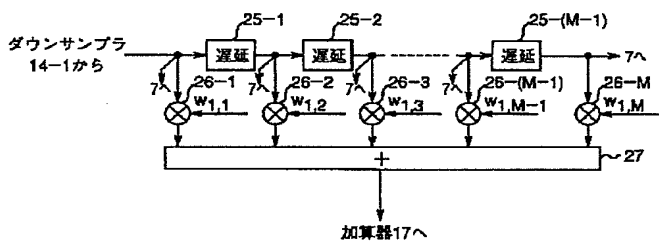


【図2】

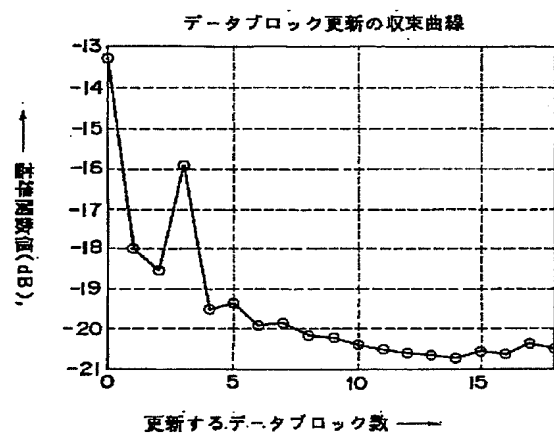


【図4】

トランスバースルフィルタ回路 23-1



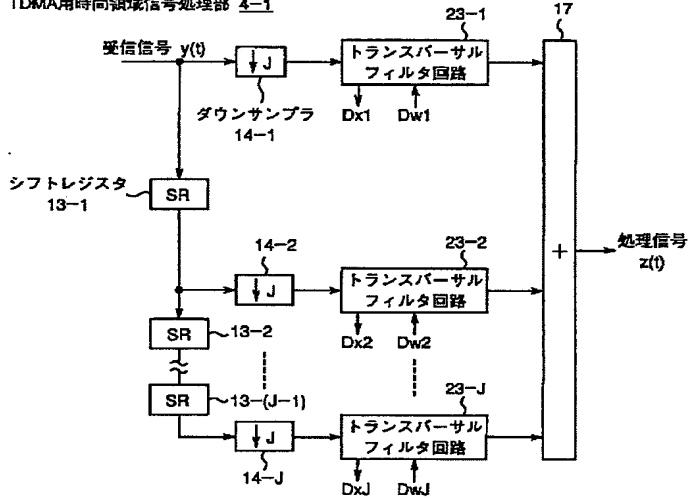
【図8】



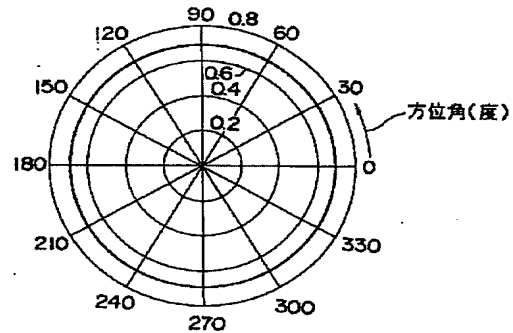
【図3】

第1の実施形態

TDMA用時間領域信号処理部 4-1



【図9】

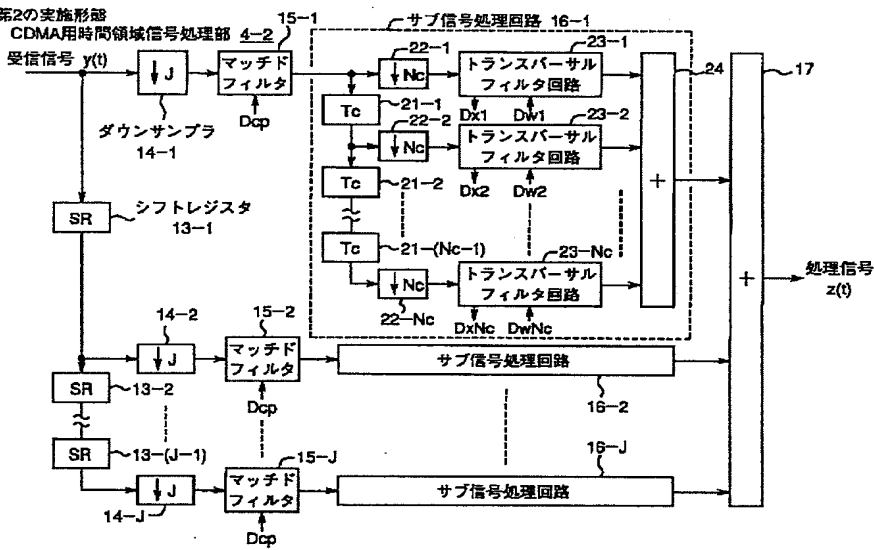


ケースA: $x^{(p)} = [0, 0, 0, 0, 0, 0, 1]^T$ のときの
ビームパターン

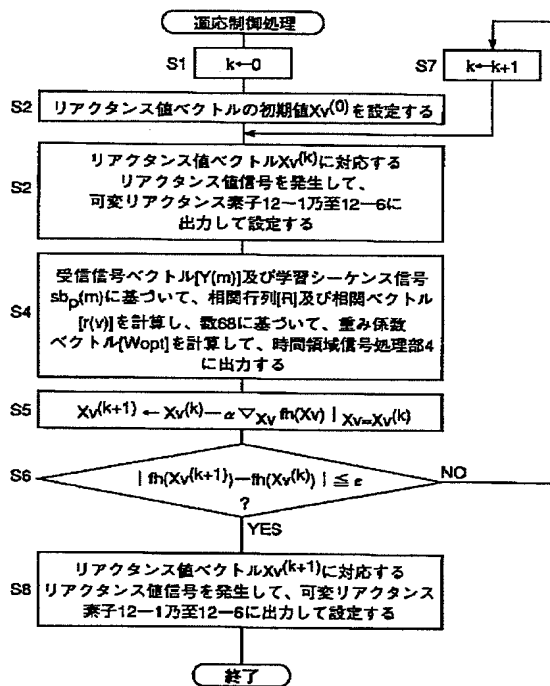
【図5】

第2の実施形態

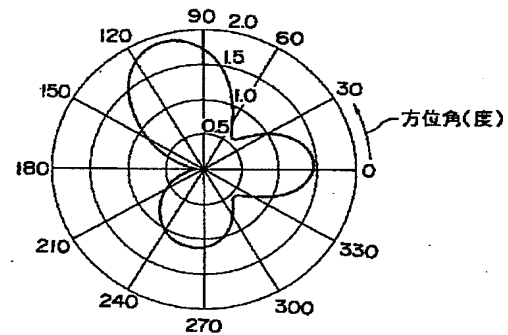
CDMA用時間領域信号処理部 4-2



【図6】

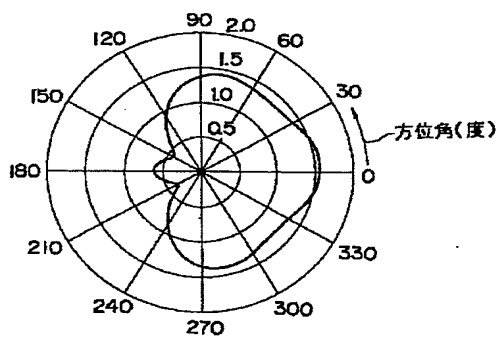


【図10】



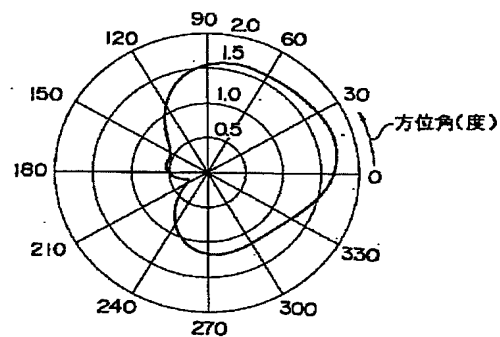
ケースB: $X^{(2)} = [5, -152, 161, 130, 36, -78]^T$
のときのビームパターン

【図11】



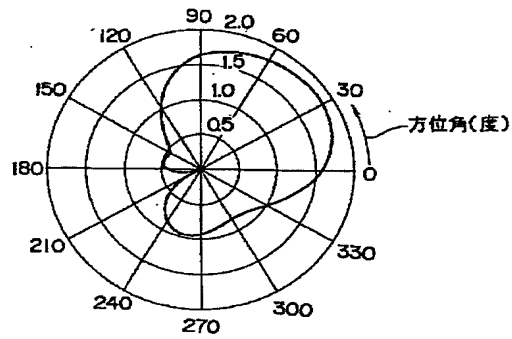
ケースC: $X^{(4)} = [132, -58, 223, 215, 130, -61]^T$
のときのビームパターン

【図12】



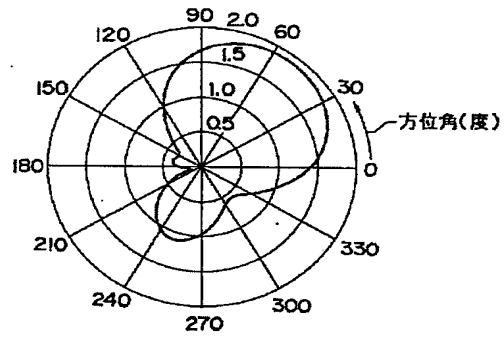
ケースD: $X^{(9)} = [216, -95, 237, 371, 51, 93]^T$
のときのビームパターン

【図13】



ケースE: $x^{(3)} = [273, -94, 254, 479, 18, -95]^T$
 のときのビームパターン

【図14】



ケースF: $x^{(3)} = [360, -89, 285, 641, -1, -80]^T$
 のときのビームパターン

フロントページの続き

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 EA04 FA14 FA15 FA16 FA17
 FA20 FA26 FA29 FA32 GA02
 HA05 HA10
 5K046 AA05 EE06 EE47 EE56 EF13
 5K059 CC03 CC04 DD31

JAPANESE [JP,2002-261531,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE
INVENTION TECHNICAL PROBLEM MEANS EXAMPLE DESCRIPTION OF DRAWINGS
DRAWINGS

[Translation done.]

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CLAIMS

[Claim(s)]

[Claim 1] The radiating element for receiving a radio signal, and two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control unit of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed The radio signal received in the above-mentioned array antenna is divided into the sub signal of two or more time domains. A time domain signal-processing means to perform signal processing of a time domain and to output as a processing signal by adding after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the above-mentioned time domain signal-processing means so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The control unit of the array antenna characterized by having the ecad control means which calculates and sets up the reactance value of each above-mentioned variable reactive element so that the gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal may be calculated and the value of the above-mentioned criterion function may serve as min.

[Claim 2] The radiating element for receiving a radio signal, and two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control approach of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed The radio signal received in the above-mentioned array antenna is divided into the sub signal of two or more time domains. The step which performs signal processing of a time domain and is outputted as a processing signal by adding after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs for signal processing of the above-mentioned time domain so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The control approach of the array antenna characterized by including the step which calculates and sets up the reactance value of each above-mentioned variable reactive element so that the gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal may be calculated and the value of the above-mentioned criterion function may serve as min.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] About the control unit and the control approach of the array antenna to which the directional characteristics of the array antenna equipment which consists of two or more antenna elements can be changed, this invention is electronics control wave director array antenna equipment (it is called an ESUPA antenna below Electronically Steerable Passive Array Radiator (ESPAR) Antenna;) to which directional characteristics can be changed especially accommodative, and relates to the control unit and the control approach of the array antenna which can process a TDMA input signal or a CDMA input signal.

[0002]

[Description of the Prior Art] An ESUPA antenna for example "The conventional technical reference 1 T.Ohira and "Microwave signalprocessing and devices for adaptive beamforming and "IEEE Antenna and Propagation society It is proposed in International Symposium vol.two, pp.583-586, Salt LakeCity, Utah July 16-21, and the patent application of 2000" and Japanese Patent Application No. No. 194487 [11 to]. This ESUPA antenna can change the directional characteristics of the above-mentioned array antenna by having the array antenna which consists of the driven element by which a radio signal is transmitted and received, at least one parasitic element by which only predetermined spacing is left and prepared from this driven element, and a radio signal is not transmitted and received, and the variable reactive element connected to this parasitic element, and changing the reactance value of the above-mentioned variable reactive element.

[0003] Moreover, multi-pass propagation and cochannel interference (CCI) exist in radiocommunication as two problems which have an adverse effect on a wireless system. These problems appear as the interference (ISI) between symbols resulting from the reuse of the frequency in a TDMA wireless system and cochannel interference, or multiuser access interference (MAI) in a CDMA wireless system, respectively.

[0004] In order to solve the above trouble, the ecad processing (STAP) between space-time (refer to the conventional technical reference 2 "J.Paulraj et al. and "Space-time processing for wireless communications" IEEE Signal Processing Magazine, Vol.14, No.6, pp.49-83, and November 1997") is proposed, and it is thought that this processing demonstrates the engine performance which stood high in control of both ISI and CCI. Recently, the approach of the ecad processing (STAP) between space-time is proposed and analyzed to TDMA or a direct diffusion (sequence) CDMA (DS-CDMA) radio communications system.

[0005]

[Problem(s) to be Solved by the Invention] However, implementation of the antenna array channel of a STAP system is complicated, and since it is high cost, it is difficult [it] to apply these widely actually especially in the situation that it is supposed like a wireless premises network system or a user-terminal machine that it is cost a very important element. This means that it is practical Important to develop the STAP system of cost easy a configuration and lower.

[0006] The object of this invention solves the above trouble, and has an easy configuration as

compared with the conventional technique, and its manufacturing cost is cheap, and it is in offering the control unit and the control approach of an array antenna that space-time adaptation processing which is for an ESUPA antenna can be performed.

[0007]

[Means for Solving the Problem] A radiating element for the control unit of the array antenna concerning this invention to receive a radio signal, Two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control unit of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed The radio signal received in the above-mentioned array antenna is divided into the sub signal of two or more time domains. A time domain signal-processing means to perform signal processing of a time domain and to output as a processing signal by adding after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the above-mentioned time domain signal-processing means so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal is calculated, and it is characterized by having the ecad control means which calculates and sets up the reactance value of each above-mentioned variable reactive element so that the value of the above-mentioned criterion function may serve as min.

[0008] Moreover, the control approach of the array antenna concerning this invention The radiating element for receiving a radio signal, and two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control approach of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed The radio signal received in the above-mentioned array antenna is divided into the sub signal of two or more time domains. The step which performs signal processing of a time domain and is outputted as a processing signal by adding after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs for signal processing of the above-mentioned time domain so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal is calculated, and it is characterized by including the step which calculates and sets up the reactance value of each above-mentioned variable reactive element so that the value of the above-mentioned criterion function may serve as min.

[0009]

[Embodiment of the Invention] Unlike the null formed with the conventional ecad algorithm, or the beam beforehand formed in advance of signal processing (formed in advance before), by this invention, the control unit and the control approach of an array antenna that a strange good beam pattern and the equalizer of a time domain can be used together, and ecad filtering between space-time can be realized are offered. It is thought that an ESUPA antenna has the capacity which forms a beam spatially towards a desired signal at the minimum cost. In this invention, the control unit and the control approach of an array antenna for realizing ecad filtering (STAF) between space-time using an ESUPA antenna for TDMA or a CDMA signal wave

form are proposed.

[0010] Hereafter, the operation gestalt of this invention is explained with reference to a drawing.

[0011] Drawing 1 is the block diagram of the control device of the array antenna of the operation gestalt concerning this invention. The control unit of the array antenna of this operation gestalt is characterized by having the array antenna equipment 100 which consisted of ESUPA antennas of the conventional technique which is equipped with one driven element A0, six parasitic elements A1, or A6, and becomes, the time domain signal processing section 4 which processes the radio signal received with the above-mentioned array antenna equipment 100, and the adaptive control mold controller 7 which controls them, as shown in drawing 1.

[0012] drawing 1 — setting — array antenna equipment 100 — touch-down — it consists of a driven element A0 prepared on the conductor 11 and a parasitic element A1 thru/or A6, and the driven element A0 is arranged as surrounded in six parasitic elements A1 prepared on the periphery of a radius r thru/or A6. Preferably, on the periphery of the above-mentioned radius r , each parasitic element A1 thru/or A6 keep regular intervals mutual, and is prepared. Each driven element A0 and a parasitic element A1 thru/or the die length of A6 are constituted so that it may become the abbreviation $1/4$ of the wavelength λ of a request wave, and the above-mentioned radius r is constituted so that it may become $\lambda/4$. The feeding point of a driven element A0 is connected to a low noise amplifier (LNA) 1 through a coaxial cable 9, and a parasitic element A1 thru/or A6 are connected to a variable reactive element 12-1 thru/or 12-6, respectively, and these variable reactive elements 12-1 thru/or the reactance value of 12-6 are set up by the reactance value signal from the adaptive control mold controller 7.

[0013] Drawing 2 is drawing of longitudinal section of array antenna equipment 100. a driven element A0 — touch-down — it insulates with a conductor 11 electrically — having — each parasitic element A0 thru/or A6 — a variable reactive element 12-1 thru/or 12-6 — minding — touch-down — it is grounded in RF to a conductor 11. If a variable reactive element 12-1 thru/or actuation of 12-6 are explained, when the die length of a radiating element A0, a parasitic element A1, or the longitudinal direction of A6 is substantially the same (for example, when a variable reactive element 12-1 has inductance nature (L nature)), a variable reactive element 12-1 serves as an extension coil, and a parasitic element A1 thru/or the electric merit of A6 will become long as compared with a driven element A0, and it will work as a reflector, for example. On the other hand, when a variable reactive element 12-1 has capacitance nature (C nature), a variable reactive element 12-1 serves as a loading condenser, and the electric merit of a parasitic element A1 becomes short as compared with a driven element A0, and it works as the wave director.

[0014] Therefore, in the array antenna equipment 100 of drawing 1, the flat-surface directivity property of array antenna equipment 100 can be changed by changing the variable reactive element 12-1 thru/or the reactance value of 12-6 connected to each parasitic element A1 thru/or A6.

[0015] In the control unit of the array antenna of drawing 1, array antenna equipment 100 receives a radio signal, through a coaxial cable 9, the signal by which reception was carried out [above-mentioned] is inputted into a low noise amplifier (LNA) 1, and is amplified, and, subsequently a down converter (D/C) 2 carries out low-pass conversion of the amplified signal at the signal (IF signal) of a predetermined intermediate frequency. Furthermore, A/D converter 3 carries out A/D conversion of the analog signal by which low-pass conversion was carried out to a digital signal, and outputs the digital signal by which A/D conversion was carried out to the time domain signal-processing section 4. Subsequently, the time domain signal-processing section 4 divides into the sub signal of two or more time domains radio-signal $y(t)$ received by array antenna equipment 100. By adding, after outputting the signal vector $[Y]$ which consists of two or more divided sub signals to the adaptive control mold controller 7 and carrying out the multiplication of the predetermined weighting factor to two or more divided sub signals, respectively, signal processing of a time domain is performed and it outputs as processing signal $z(t)$. And the adaptive-control mold controller 7 calculates an error signal by subtracting above-mentioned processing signal $z(t)$ from the study sequence signal generated by the study sequence signal generator 6, and further, the adaptive-control mold controller 7 performs

adaptive-control processing by calculating the optimal weighting-factor vector $[W]$, and outputting to the time-domain signal-processing section 4 so that an error signal may serve as min based on the above-mentioned study sequence signal and a signal vector $[Y]$. Specifically here the adaptive control mold controller 7 Based on a study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the time domain signal-processing section 4 so that the error signal of processing signal $z(t)$ and a study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal is calculated, and each variable reactive element 12-1 thru/or the reactance value of 12-6 are calculated and set up so that the value of the above-mentioned criterion function may serve as min.

[0016] According to the digital data signal of a predetermined symbol rate including the same study sequence signal as the predetermined study sequence signal generated with the study sequence signal generator 6, the sending station which transmits the radio signal received with an array antenna 100 modulates the carrier signal of a radio frequency using digital modulation methods, such as QPSK, or the direct diffuse-spectrum diffusion becoming [irregular] method, carries out power amplification of the modulating signal concerned, and transmits it towards the array antenna equipment 100 of a receiving station. In the operation gestalt concerning this invention, before performing data communication, the radio signal which includes a study

sequence signal towards a receiving station from a sending station is transmitted, and adaptive control processing by the adaptive control mold controller 7 is performed in a receiving station. [0017] Next, with reference to drawing 3 thru/or drawing 5, the time domain signal-processing section 4 of drawing 1 is explained more to a detail. Drawing 3 is the block diagram of the time domain signal-processing section 4-1 for TDMA which is the 1st operation gestalt of the time domain signal-processing section 4. two or more [(shift register SR) 13-1 thru/or 13-(J-1) of two or more (J-1) individuals to which cascade connection of the time domain signal-processing section 4-1 for TDMA was carried out mutually, and] — two or more [J down samplers 14-1 thru/or 14-J, and] — it has J transversal filter circuits 23-1 thru/or 23-J, and an adder 17, and is constituted. The above-mentioned shift register (SR) 13-1 thru/or 13-(J-1) delay for it and output only 1 symbol period for an input signal based on the clock inputted, respectively. The multiplication of the weighting-factor data $Dw1$ which outputted the signal data $Dx1$ divided into the sub signal of two or more time delay thru/or DxJ to the adaptive control mold controller 7, and were calculated by the adaptive control mold controller 7 for the operation of a weighting factor thru/or the DwJ is carried out to each signal into which it was inputted, and the transversal filter circuit 23-1 thru/or 23-J output it to it.

[0018] Input-signal $y(t)$ outputted from A/D converter 3 of drawing 1 is inputted into a shift register 13-1 as the down sampler 14-1. The down sampler 14-1 carries out the down sampling of the inputted input-signal $y(t)$ with a sampling frequency $1/J$ time the sampling frequency of A/D converter 3, and outputs the signal after processing to an adder 17 through the transversal filter circuit 23-1 which carries out the detail after-mentioned. The signal outputted from the shift register 13-1 is inputted into a shift register 13-2 as the down sampler 14-2. The down sampler 14-2 carries out the down sampling of the inputted signal with a sampling frequency $1/J$ time the sampling frequency of A/D converter 3, and outputs the signal after processing to an adder 17 through the transversal filter circuit 23-2. The signal outputted from shift register 13-j ($j = 2, 3, \dots, J-1$) is outputted to down sampler 14-(j+1) and shift register 13-(j+1) like the following. Down sampler 14-(j+1) carries out the down sampling of the inputted signal with a sampling frequency $1/J$ time the sampling frequency of A/D converter 3, and outputs the signal after processing to an adder 17 through transversal filter circuit 23-(j+1). two or more [furthermore, / into which the adder 17 was inputted] — J signals are added and the signal of an addition result is outputted as processing signal $z(t)$.

[0019] Drawing 4 is the block diagram showing the configuration of the transversal filter circuit 23-1 of drawing 3. With the delay circuit 25-1 of two or more (M-1) individuals thru/or 25-(M-1) to which only $1/4$ of one symbol thru/or the time amount of $1/2$ were delayed, respectively, and cascade connection was mutually carried out, the transversal filter circuit 23-1 is equipped with two or more M multipliers 26-1 thru/or 26-M, and adders 27, and the signal inputted by

passing the down sampler 22-1 is constituted. The signal inputted into the transversal filter circuit 23-1 it outputs to the adaptive control mold controller 7 as data of a sub signal — having — and weighting-factor w , while being outputted to an adder 27 through the multiplier 26-1 which has the multiplication multiplier of 1 and 1. It is outputted to an adder 27 through the delay circuit 25-1 of an individual $(M-1)$ thru/or 25- $(M-1)$ by which cascade connection was carried out mutually, and multiplier 26- M which has the multiplication multiplier of weighting factors w_1 and M . Here, the suffix of weighting-factor w expresses the transversal filter circuit 23-1 the serial number 1 of 23-J thru/or J with the 1st suffix, and expresses each above-mentioned transversal filter circuit 23-1 the serial number 1 of the multiplier in 23-J thru/or M with the 2nd suffix. moreover — while the signal outputted from a delay circuit 25-1 is outputted to the adaptive control mold controller 7 — weighting-factor w — while the signal which is outputted to an adder 27 through the multiplier 26-2 which has the multiplication multiplier of 1 and 2, and is further outputted from a delay circuit 25-2 is outputted to the adaptive control mold controller 7 — weighting-factor w — it is outputted to an adder 17 through the multiplier 26-3 which has the multiplication multiplier of 1 and 3. Like the following, the signal outputted from delay circuit 26- m_a ($m_a=3, \dots, M-1$) is outputted to an adder 27 through multiplier 26- (m_a+1) which has a weighting factor w_1 and the multiplication multiplier of m_a+1 while it is outputted to the adaptive control mold controller 7. And an adder 27 adds M signals inputted and outputs the signal of an addition result to an adder 17.

[0020] Moreover, with the delay circuit of two or more $(M-1)$ individuals by which cascade connection was carried out mutually, the transversal filter circuit 23-2 of drawing 3 thru/or 23-J are equipped with two or more M multipliers and adders, and is constituted like the transversal filter circuit 23-1. The time domain signal-processing section 4 compounds the signal data Dx_1 outputted from each transversal filter circuit 23-1 thru/or 23-J thru/or Dx_J to a signal vector $[Y]$, and outputs it to the adaptive control mold controller 7. Moreover, the time domain signal-processing section 4 decomposes into the weighting-factor data Dw_1 thru/or Dw_J , and carries out the multiplication of the weighting-factor vector $[W]$ inputted from the adaptive control mold controller 7 to the signal inputted there in each transversal filter circuit 23-1 thru/or 23-J.

[0021] Drawing 5 is a block diagram of the time domain signal-processing section 4-2 for CDMA concerning the 2nd operation gestalt of the time domain signal-processing section 4 which replaces the 1st operation gestalt of drawing 3. In this operation gestalt, instead of the transversal filter circuit 23-1 concerning the 1st operation gestalt thru/or 23-J They are J matched filters (it is also called a matched filter.) two or more. [matched filter;] It is characterized by having 15-1 thru/or 15-J, and the sub digital disposal circuit 16-1 thru/or 16-J connected to each above-mentioned matched filter 15-1 thru/or 15-J. The other configuration is the same as that of the time domain signal-processing section 4-1 for TDMA of the 1st operation gestalt, and the detailed explanation is omitted.

[0022] In drawing 5, $J-1$ shift register 13-1 thru/or 13- ($J-1$) by which cascade connection was carried out mutually, and J down samplers 14-1 thru/or 14-J is constituted like the time domain signal-processing section 4-1 for TDMA. The signal outputted from the down sampler 14-1 is inputted into a matched filter 15-1, and a matched filter 15-1 detects the request wave signal buried into white noise with the greatest SN ratio based on the data D_{cp} of the diffusion sign of the user terminal of a request wave into which the signal by which the down sampling was carried out is inputted from the controller (not shown) of a receiver, and, specifically, outputs a pulse signal for every period of a diffusion sign. Subsequently, the signal from a matched filter 15-1 is outputted to an adder 17 through the sub digital disposal circuit 16-1 which carries out the detail after-mentioned. Moreover, the signal outputted from the down sampler 14-2 is outputted to an adder 17 through a matched filter 15-2 and the sub digital disposal circuit 16-2. Each matched filter 15- j ($j=3, 4, \dots, J$) outputs like the following the signal outputted from down sampler 14- f_a to an adder 17 through sub digital-disposal-circuit 16- j .

[0023] Subsequently, the detail configuration of the sub digital disposal circuit 16-1 of drawing 5 is explained. With the delay circuit 21-1 of two or more (N_c-1) individuals thru/or 21- (N_c-1) by which cascade connection was carried out by having the predetermined time delay T_c , respectively, the sub digital disposal circuit 16-1 is equipped with two or more transversal filter

circuits 23-1 of N_c individual thru/or 23- $N_c(s)$, and adders 24 with the down sampler 22-1 of N_c individual thru/or 22- N_c , and are constituted. [two or more] The signal outputted from the matched filter 15-1 is outputted to a delay circuit 21-1 and the down sampler 22-1. The down sampler 22-1 carries out the down sampling of the inputted signal with a sampling frequency $1/N_c$ time the sampling frequency [the down sampler 14-1 thru/or] of 14-J, and outputs the signal after processing to an adder 24 through the transversal filter circuit 23-1.

[0024] The transversal filter circuit 23-1 thru/or 23- N_c output the signal data $Dx1$ thru/or DxN_c divided into the sub signal of two or more time delay for the operation of a weighting factor to the adaptive control mold controller 7, and carries out the multiplication of the data $Dw1$ thru/or DwN_c of a weighting factor calculated by the adaptive control mold controller 7 to each inputted signal, respectively. The transversal filter circuit 23-1 thru/or the detail configuration of 23- N_c are the same as that of the transversal filter circuit of the time domain signal-processing section 4-1 for TDMA concerning the 1st operation gestalt (refer to drawing 4). Here, in order to distinguish each weighting-factor w by which multiplication is carried out, the serial number 1 of the transversal filter circuit in each above-mentioned sub digital disposal circuit thru/or N_c shall be expressed with the 2nd suffix, and the suffix of weighting-factor w shall express the serial number 1 of the multiplier in each above-mentioned transversal filter circuit thru/or M with the 1st suffix for the sub digital disposal circuit 16-1 the serial number 1 of 16-J thru/or J by the 3rd suffix.

[0025] Moreover, the signal outputted from the delay circuit 21-1 is inputted into a delay circuit 21-2 and the down sampler 22-2, and the down sampler 22-2 carries out the down sampling of the inputted signal with a sampling frequency $1/N_c$ time the sampling frequency [the down sampler 14-1 thru/or] of 14-J, and outputs the signal after processing to an adder 24 through the transversal filter circuit 23-2. Like the following the signal outputted from delay circuit 21- nc ($nc=2, 3, \dots, N_c-1$) It is inputted into delay circuit 21- ($nc+1$) and down sampler 22- ($nc+1$). Down sampler 22- ($nc+1$) carries out the down sampling of the inputted signal with a sampling frequency $1/N_c$ time the sampling frequency [the down sampler 14-1 thru/or] of 14-J. The signal after processing is outputted to an adder 24 through transversal filter circuit 23- ($nc+1$). Furthermore, an adder 24 adds the signal of a two or more $N_c(s)$ individual inputted, and outputs the signal of an addition result to an adder 17.

[0026] The interior is constituted by the sub digital disposal circuit 16-2 thru/or 16-J as well as the sub digital disposal circuit 16-1. two or more [to which an adder 17 is outputted from the sub digital disposal circuit 16-1 thru/or 16-J] — J signals by which adaptive control was carried out are added, and the signal of an addition result is outputted as processing signal $z(t)$. The time domain signal-processing section 4 compounds the signal data $Dx1$ thru/or DxN_c outputted from the sub digital disposal circuit 16-1 each transversal filter circuit 23-1 of the two or more $J \times N_c$ individual in 16-J thru/or 23- N_c to a signal vector $[Y]$, and outputs it to the adaptive control mold controller 7. Moreover, the time domain signal-processing section 4 decomposes into the weighting-factor data $Dw1$ thru/or DwN_c , and carries out the multiplication of the weighting-factor vector $[W]$ inputted from the adaptive control mold controller 7 to the signal inputted there in each transversal filter circuit 23-2 of a two or more $J \times N_c$ individual thru/or 23- N_c .

[0027] In the control unit of the array antenna constituted as mentioned above The adaptive control mold controller 7 is based on the signal vector $[Y]$ outputted from the time domain signal-processing section 4, and a predetermined study sequence signal. a minimum of [for example,] — an error signal serves as min using the predetermined adaptive control algorithm using error (MMSE) criteria the 2nd [an average of] power — as — two or more — each weighting factor for the $J \times N_c \times M$ piece multiplier 26-1 thru/or 26-M is calculated, and it is fed back and set as each multiplier 26-1 thru/or 26-M.

[0028] The adaptive control mold controller 7 outputs the reactance value signal for controlling the directivity of array antenna equipment 100 further. The adaptive control mold controller 7 here For example, the sub signal generated in the time domain signal-processing section 4 before consisting of digital computers, such as a computer, and starting data communication, It is based on the study sequence signal $sbp(m)$ generated with the study sequence signal

generator 6. By performing adaptive control processing illustrated by the flow chart of drawing 6 It is characterized by calculating and setting up each variable reactive element 12-1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance values X_1, \dots, X_6 of 12-6. The adaptive control mold controller 7 is made to specifically precess each variable reactive element 12-1 thru/or the reactance values X_1, \dots, X_6 of 12-6 only for predetermined shift-amount ΔX one by one. The gradient vector of the predetermined criterion function (function f_h with the study sequence signal s_{bp} in several 68 later mentioned with this operation gestalt (m) by which generating was carried out [above-mentioned] with the sub signal calculated from input-signal $y(t)$ which makes each reactance value a variable is calculated. Subsequently, the reactance values X_1, X_2, \dots, X_6 are calculated so that the criterion function value concerned may serve as max based on the calculated gradient vector. The reactance value signal which consists of reactance values X_1, X_2, \dots, X_6 is turned and outputted to a variable reactive element 12-1 thru/or 12-6. By it [0029] set up so that the main beam of the above-mentioned array antenna equipment 100 may be turned in the direction of a request wave and null may be turned in the direction of an interference wave Subsequently, the control unit of the array antenna of the operation gestalt concerning this invention and the principle of the control approach are explained.

[0030] The model of the signal which arrives at the antenna array which consists of components of N ($N > 1$) individual which has introduction and P persons' user terminal is considered. the radio signal transmitted from the sending station — touch-down — incidence is carried out by the incident angle (it is also called an arrival angle (Angle of Arrival;AOA).) θ defined in the flat surface containing a conductor 11, and it is received by array antenna equipment 100. With this operation gestalt, the direction of a parasitic element A1 is determined as $\theta = 0$ focusing on a driven element A0. The baseband wave signal s_p of the p -th user terminal of the signal transmitted (t) is expressed as follows.

[0031]

[Equation 1]

$$s_p(t) = \sum_{m=-\infty}^{+\infty} s_{bp}(m) \rho_p(t - mT)$$

[0032] Here, $s_{bp}(m)$ shows the m -th information symbol concerning the signal of the p -th user terminal, and $\rho_p(t)$ expresses an information symbol wave. By the TDMA system, to the signal of each user terminal, information symbol wave $\rho_p(t)$ has many same things, and is considered as a cosine modulated wave form by which the spread spectrum was carried out. T shows the symbol persistence time or a symbol period. In a CDMA system, a degree type is materialized and this is called the pulse-shape plastic surgery function of the p -th user terminal.

[0033]

[Equation 2]

$$\rho_p(t) = \sum_{j=0}^{N_c-1} c_p(j) \Psi(t - jT_c)$$

($0 \leq t \leq T$)

[0034] It is the $\{c_p(j)\}$, $j = 0, \dots$, diffusion code by which $N_c - 1$ was assigned to the p -th user terminal, T is symbol duration time equal to the product of the chip spacing T_c and the number N_c of chips per symbol here, and $\psi(t)$ is a chip wave signal which is defined by the time amount section $[0, T_c]$ and which it normalized. Furthermore, when an over sampling technique period is set to Δ , it is $T_c/\Delta = 2$, and when a transmission bit rate is set to f_b , a symbol bit rate is expressed with $2 \times 127 \times f_b$. The diffusion sign sequence may be periodic depending on the specification to adopt, or may be aperiodic. this application description considers the case of being periodic. The array input-signal vector $[x(t)]$ of N dimension received with the array antenna equipment without a noise which consists of an antenna element of N individual is expressed as follows. Hereafter, a vector or a matrix is expressed with $[-]$ in this application description.

[0035]

[Equation 3]

$$\begin{aligned} [\mathbf{x}(t)] &= \sum_{p=1}^P \sum_{l=1}^{L_p} [\mathbf{a}(\theta_l^p)] \xi_l^p s_p(t - \tau_l^p) \\ &= \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) [\mathbf{g}_p(t - mT)] \end{aligned}$$

[0036] Here, several 3 inner N dimension vector $[\mathbf{g}_p(t)]$ is called the channel impulse response between space-time of the symbol wave signal between space-time of the p-th user terminal, or symbol level like a degree type.

[0037]

[Equation 4]

$$[\mathbf{g}_p(t)] = \sum_{l=1}^{L_p} [\mathbf{a}(\theta_l^p)] \xi_l^p \rho_p(t - \tau_l^p)$$

[0038] θ_l^p , τ_l^p , and ρ_l^p express the arrival angle (AOA) corresponding to the l-th path, the time delay, and the propagation loss of a signal of the p-th user terminal, respectively.

Furthermore, N dimension vector $[\mathbf{a}(\theta)]$ expresses the Ares tearing vector corresponding to θ , and $s_p(m)$ and L_p show the total of the m-th information symbol concerning the signal of the p-th user terminal, and a multi-pass wave, respectively. The following matters are assumed to several 3 component.

<Assumption 1> The signal to receive is the periodic steady state of a wide sense, when sampled the symbol period of fraction spacing (fractionally spaced), and when sampled at a symbol rate, it is the steady state of a wide sense. The signal vector $[\mathbf{x}(t)]$ of the periodic steady state of a wide sense is defined by the degree type.

[0039]

[Equation 5] $E\{[\mathbf{x}(t_1)][\mathbf{x}(t_2)]^H\} = E\{[\mathbf{x}(t_1+T)][\mathbf{x}(t_2+T)]^H\}$

[0040] Here, $[-]^H$ shows conjugation transposition and $E\{[-]\}$ shows statistical expected value. the <assumption 2> information symbol $s_p(m)$ and $p = 1, 2, \dots, P$ are independence and the same distribution, and fill a degree type.

[0041]

[Equation 6]

$E\{s_p(m) s_p^*(n)\} = \delta_{m,n}$ [0042] Here, $[-]^*$ shows a complex conjugate and δ and q show a Kronecker's delta function.

the channel $\{\mathbf{g}_p(t)\}$ of <assumption 3> plurality, and $p = 1, 2, \dots, P$ between the periods by which 1, 2, ..., the interest to which P carries out predetermined data communication were held --- linearity --- and it is eternal in time and belongs to the persistence time of finite within the time amount section $[0, D_pT]$.

[0043] Next, it formulizes about the model of the signal received especially with array antenna equipment 100. Input-signal $y(t)$ without the noise outputted from array antenna equipment 100 equipped with the driven element A0 which drawing 1 shows and a parasitic element A1 thru/or A6 is specified by the degree type (see the conventional technical reference 3 "Ohira *****, "equivalence wait vector [of an ESUPA antenna] and array factor expression", Institute of Electronics, Information and Communication Engineers technical report, A-P 2000-44, SAT 2000-41, and MW2000-July, 2000 [44 or]").

[0044]

[Equation 7] $y(t) = [\mathbf{i}]^T [\mathbf{x}(t)]$

[0045] Moreover, a steering vector $[\mathbf{a}(\theta)]$ is expressed with a degree type.

[0046]

[Equation 8] $[\mathbf{a}(\theta)] = (1, \exp(j(2\pi r/\lambda) \cos(\theta)), \dots, \exp(j(2\pi r/\lambda) \cos(\theta - 5 \times 2\pi/6)))^T$ [0047] Here, the diameters of an array are $r = \lambda/4$, λ expresses the wavelength of the radio frequency of a request wave, and the equivalence wait vector $[\mathbf{i}]$ considered in the conventional technical reference 3 is drawn like a degree type.

[0048]

[Equation 9] $[i]=C[I+YX]-1[y0]$

[0049] Here, I is a unit matrix.

[0050]

[Equation 10] $[y0]=[y00, y10, y10, y10, y10, y10, y10]^T$ — [Equation 11]

$$X = \begin{bmatrix} R_0 & & & & & & 0 \\ & j X_1 & & & & & \\ & & \ddots & & & & \\ 0 & & & j X_6 & & & \end{bmatrix}$$

[Equation 12]

$$Y = \begin{bmatrix} y_{00} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} \\ y_{10} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} \\ y_{10} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} \\ y_{10} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} \\ y_{10} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} \\ y_{10} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} \\ y_{10} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} \end{bmatrix}$$

[0051] X is a reactance matrix for adjusting the pattern of an antenna, $R_0=50\text{ohm}$ is the input impedance of a radio set, and X_1, \dots, X_6 are parameters outputted as a reactance value signal from the adaptive control mold controller 7. The admittance matrix to which Y expresses the cross coupling between the components of an antenna, and $[y0]$ are the related admittance vectors, and contain the following [component / the].

[0052] (a) y_{00} expresses the self-input admittance of a driven element A0.

(b) y_{10} expresses a driven element A0, a parasitic element A1, or the joint admittance of A6.

(c) y_{11} expresses a parasitic element A1 thru/or the self-input admittance of A6.

(d) y_{21} expresses the joint admittance of the parasitic element A1 which adjoins mutually, A2 and A2, A3 and A3, A4 and A4, A5 and A5, A6, or A6 and A1.

(e) y_{31} expresses the joint admittance of two parasitic elements A1 located in a line on both sides of one parasitic element in between, A3, A2, A4 and A3, A5 and A4, A6 and A5, A1, or A6 and A2, and (f) y_{41} express two parasitic elements A1 which counter on both sides of a driven element A0, A4, A2 and A5, or the joint admittance of A3 and A6.

[0053] Because of reciprocity and the patrol-symmetric property of array antenna equipment 100, only six components are independent as mentioned above. Moreover, C is a multiplier about the gain of an antenna. When it is array antenna equipment 100 which drawing 1 shows, the value of $C=131.2$ has been acquired from the actual measurement result in approximation. The admittance vector $[y0]$ and a different input value (entry) to admittance-matrix Y are shown in a table 1.

[0054]

[A table 1]

----- $y_{00}=0.00860035-0.0315844j$ $y_{10}=-$

$0.00372642+0.0072319j$ $y_{11}=0.00962295-0.01656835j$ $y_{21}=-$

$0.000377459+0.0117867j$ $y_{31}=0.00002720885-0.0063736j$ $y_{41}=0.001779525+0.002208335j$ -----

[0055] If several 3 is substituted for several 7 and additive noise is taken into consideration, input-signal $y(t)$ outputted from the single port of array antenna equipment 100 can be expressed like a degree type.

[0056]

[Equation 13]

$$y(t) = [i]^T [x(t)] \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} b_p(m) g a_p(t-mT) + n(t)$$

[0057] Here, the following function contained in several 13 is also called the symbol wave signal between space-time of the p-th user terminal.

[0058]

[Equation 14]

$$\begin{aligned}
 g_{a_p}(t) &= [i]^T [g_p(t)] \\
 &= \sum_{i=1}^{L_p} [i]^T [a(\theta_i^p)] \xi_i^p \rho_p(t - \tau_i^p) \\
 &= \sum_{i=1}^{L_p} f(\theta_i^p) \xi_i^p \rho_p(t - \tau_i^p)
 \end{aligned}$$

[0059] Here, $f(\theta)$ expressed with a degree type is the pattern of array antenna equipment 100.

[0060]

[Equation 15] $f(\theta) = f(\theta, X_1, \dots, X_6) = [i]^T [a(\theta)]$

[0061] The impulse response g_p between [of two] space-time (t) and $[g_p(t)]$ have the clearly same persistence time. Additive noise has satisfied the following assumptions.

<Assumption 4> additive noise is a white noise of a zero average with which the following two formulas are filled, and was not correlated with the signal of a user terminal.

[0062]

[Equation 16] $E[n_2(t)] = 0$ — [Equation 17] $E[n(t)^2] = \sigma^2$ [0063] Here, σ^2 express the power of a noise.

[0064] As for several 9 thru/or several 14, the output signal of array antenna equipment 100 also shows that it is the nonlinear function of reactances X_1, X_2, \dots, X_6 .

[0065] Next, ecad filtering between space-time for removing the signal which is not desirable performed in the time domain signal-processing section 4 is explained. The variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 perform time processing of the control unit of the array antenna when having the set of the given reactance value first using the time domain signal-processing section 4-1 for TDMA illustrated by drawing 3. In the case of TDMA, processing is performed based on a symbol wave signal. A shift register 13-1 thru/or the sampling period in 13- (J-1) are expressed with Δ , and let $J = T/\Delta$ (J is one or more integers) be the multiplier of over sampling technique. If input-signal $y(t)$ is sampled by assumption A2 by time amount $t = i\Delta + mT$ (here, m the integer of arbitration; $i = 0, 1, \dots, J-1$), several 13 will become like a degree type.

[0066]

[Equation 18]

$$\begin{aligned}
 y(i\Delta + mT) \\
 = \sum_{p=1}^P \sum_{d=0}^{D_p} b_p(m-d) g_{a_p}(i\Delta + dT) + n(i\Delta + mT)
 \end{aligned}$$

($i = 0, 1, \dots, J-1$)

[0067] The periodic steady state of the signal of the terminal described by the assumption A1 If it uses () [conventional technical reference 4 "L.Tong] et al., "Blind identification and equalization based on second-order statistics : a time domain approach and" IEEE Transaction. Information Theory, Vol.40, pp.340-349, and refer to March 1994." The approach of a multichannel model that the transversal filter circuit 23-1 which is the equalizer of fraction spacing illustrated by drawing 3 thru/or 23-J were extended is easily establishable like a degree type.

[0068]

[Equation 19]

$$[y_b(m)] = \sum_{p=1}^P \sum_{d=0}^{D_p} b_p(m-d) [h_p(d)] + [n_b(m)]$$

[0069] Here, the impulse response vector between [of J dimensions] signal vector $[y_b(t)]$ space-time $[h_p(d)]$ and a noise vector $[n_b(m)]$ are expressed with a degree type.

[0070]

[Equation 20] $[y_b(m)] = (y(mT), \text{ and } [y(mT-\Delta), \dots, y(mT-(J-1)\Delta)])^T$ — [Equation 21]

[hp(d)]=(gap (dT), and [gap (dT-delta), —, gap (dT-(J-1) delta)]) T — [Equation 22] [nb(m)]=(n (mT), and [n (mT-delta), —, n (mT-(J-1) delta)]) T [0071] The dimension of an input signal [yb (m)] is J each about m, and J is called "the number of over sampling technique channels." About the limitation of the number of extended channels by over sampling technique, the conventional technical reference 5 (A.J.van der Veen, "Resolutionlimits of blind multi-user multi-channel identification scheme—the band-limited case", and "in Proceeding of ICASSP'96, Atlanta, GA and May 1996") argues. About the continuation sample in the period of a symbol of M pieces, the following JxM dimension signal vector [YT (m)], the symbol vector [Sp (m)] which consists of an information symbol of the M+Dp individual concerning the signal of the p-th user terminal, and a JxM dimension noise vector [N (m)] are formed.

[0072]

[Equation 23] [YT(m)]=(yb (m), and [yb (m-1), —, yb (m-M +1)]) T — [Equation 24] [Sp(m)] = (sbp (m), and [sbp (m-1), —, sbp (m-M-Dp +1)]) T — [Equation 25] [N(m)]=(nb (m), and [nb (m-1), —, nb (m-M +1)]) T [0073] next Silvester (Sylvester) concerning user-terminal p — if it collapses and the term of impulse response [of the die length (dimension) of x(Dp+1) J of the channel] [[hp(0)] T, [hp(1)] T, —, [hp(Dp)] T] T defines a matrix, it will become a MJx (M+Dp) degree matrix like a degree type.

[0074]

[Equation 26]

$$[H_p^{(M)}] = \begin{bmatrix} [h_p(0)] & \cdots & [h_p(D_p)] & 0 & \cdots & \cdots & 0 \\ 0 & [h_p(0)] & \cdots & [h_p(D_p)] & 0 & \cdots & 0 \\ \vdots & \ddots & \cdots & \ddots & \cdots & \ddots & \vdots \\ 0 & \cdots & \cdots & 0 & [h_p(0)] & \cdots & [h_p(D_p)] \end{bmatrix}$$

[0075] Here, "0" expresses zero J-dimensional vector. Several 19 is extensible to a degree type.

[0076]

[Equation 27]

$$[Y_T(m)] = \sum_{p=1}^P [H_p^{(M)}] [S_p(m)] + [N(m)]$$

[0077] Therefore, equalization to the sub signal in the time domain signal-processing section 4-1 for TDMA can be performed by the degree type.

[0078]

[Equation 28] zT(m)=[W]T[YT(m)]

[0079] It is here and is [Equation 29]. [W]=[— w — it is a weighting-factor vector for 1, 0, —, wJ0, —, w1, M-1, — and the transversal filter circuit 23-1 that is the equalizer with which wJ and M-1]T were illustrated by drawing 4. the minimum average square error (MMSE) criteria — being based — the optimal weighting factor for the transversal filter circuit 23-1 — the solution from several 30 — it is given by the solution of him and the well-known Wiener-hop, several 31 [i.e.,].

[0080]

[Equation 30]

$$m_{[W]} \min E|s_{b_1}(m-v) - z_T(m)|^2$$

[Equation 31]

[WMMSE]*=[RT]-1[r(v)]

[0081] Here, sb1 (m) is the study sequence signal of the signal of a desired user terminal, and v>=0 is delay of a study sequence signal required for implementation of causal filtering (causal filtering) in consideration of a time delay v. Adaptive control of the adaptive control mold controller 7 is carried out by calculating a weighting-factor vector [W] so that the error of the signal sb1 (m-v) with which only the predetermined time delay v was delayed in the study

sequence signal, and the processing signal $z_T(m)$ may serve as min so that clearly from several 30. [RT] and $[r(v)]$ are the correlation vectors between the temporal phase Seki matrix of the signal vector calculated as follows, respectively, a study sequence signal, and a signal vector. [0082]

[Equation 32] $[RT] = E\{[YT(m)][YT(m)]^H\}$

[Equation 33] $[r(v)] = E\{sb1*(m-v)[YT(m)]\}$

[0083] The adaptive control mold controller 7 outputs the weighting-factor vector $[W]$ searched for by several 31 thru/or 33 to the time domain signal-processing section 4, in the multiplier 26-1 of a $J \times M$ individual thru/or 26-M, the multiplication of two or more weighting-factor vectors $[W]$ is carried out to a signal vector $[YT]$, the signal of a multiplication result is added with adders 27 and 17, and they are outputted. The adaptive control mold controller 7 makes the residuum power of an output signal $z_T(k)$ minimize by repeating above-mentioned processing and completing several 30 error based on the error signal of the Signal $z_T(k)$ and the study sequence signal which were outputted. Moreover, the minimum residuum power in case the variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 have the set of the given reactance value is called for like a degree type. [0084]

[Equation 34]

$$\begin{aligned} \sigma_{T_MMS\ E}^2(v) \mid_{x_1, \dots, x_6} &= E\{s \mid b_1(m-v) - z_T(m)\}^2 \\ &= E\{s \mid b_1(m-v)\}^2 - [W_{MMS\ E}]^T [R_T] [W_{MMS\ E}]^* \\ &= E\{s \mid b_1(m)\}^2 - [r(v)]^H [R_T]^{-1} [r(v)] \end{aligned}$$

[0085] Actually, the minimum residuum power of several 34 is the function of the reactance values X_1, \dots, X_6 .

[0086] The variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 explain the case where the time domain signal-processing section 4-2 for CDMA illustrated by drawing 5 next in time domain processing of the control unit of the array antenna when having the set of the given reactance value is used. In the case of CDMA, the time domain processing concerned is performed to pulse-shape plastic surgery functions and those related matched filters 15-1 thru/or the output signal from 15-J. the sampling period in a shift register 13-1 thru/or 13- (J-1) $\Delta = T_c/J$ being shown (over sampling technique multiplier whose J is the natural number) \rightarrow input-signal $y(t) \rightarrow$ time amount $t = l\Delta T_c - i\Delta$ and ($l \rightarrow$ natural number; $i \rightarrow$ if it samples by 0, 1, $\dots, J-1$), the discrete format of several 13 will become like a degree type. [0087]

[Equation 35]

$$\begin{aligned} y(l\Delta T_c - i\Delta) \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s \mid b_p(m) \mid g_{a_p}(l\Delta T_c - i\Delta - mT) + n(l\Delta T_c - i\Delta) \end{aligned}$$

[0088] If the discretized input signal $y(l\Delta T_c - i\Delta)$, $i = 0, \dots, J-1$ are accumulated, a signal vector like a degree type will be acquired. [0089]

[Equation 36]

$$\begin{aligned} [y_v(l\Delta T_c)] \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s \mid b_p(m) \mid [g_{v_p}(l\Delta T_c - mT)] + [n_v(l\Delta T_c)] \end{aligned}$$

[0090] Here, $[y_v(l\Delta T_c)]$, $[g_{v_p}(l\Delta T_c)]$, and $[n_v(l\Delta T_c)]$ mean as follows a signal vector, the symbol wave signal between space-time, and the J -dimensional vector that shows a noise, respectively. [0091]

[Equation 37] $[y_v(l\Delta T_c)] = [y(l\Delta T_c), \dots, y(l\Delta T_c - (J-1)\Delta)]^T$ [Equation 38] $[g_{v_p}(l\Delta T_c)] = [g_{a_p}(l\Delta T_c), \dots, g_{a_p}(l\Delta T_c - (J-1)\Delta)]^T$ [Equation 39] $[n_v(l\Delta T_c)] = [n(l\Delta T_c), \dots, n(l\Delta T_c - (J-1)\Delta)]^T$ [0092] A degree type is assumed about the chip wave which it normalized. [0093]

[Equation 40] $\psi(kT_c - lT_c) = \delta_{kl}$ [0094] At this time, the discrete pulse-shape plastic surgery function of the p -th user terminal is shown by the degree type.

[0095]

[Equation 41]

$$\begin{aligned} \rho_p(lT_c) &= \sum_{j=0}^{N_c-1} c_p(j) \Psi(lT_c - jT_c) \\ &= \sum_{j=0}^{N_c-1} c_p(j) \delta_{l,j} \\ &= c_p(lT_c) \end{aligned}$$

($0 \leq l \leq N_c - 1$)

[0096] It is [Equation 42] in order to simplify a notation. If $c_{bp}(lT_c) = c_p(N_c - lT_c)$ and $0 \leq l \leq N_c - 1$, a degree type can show the output-signal vector after carrying out back-diffusion of gas of the pulse-shape plastic surgery function of a p_0 position user terminal by the matched filter 15-1 thru/or 15-J.

[0097]

[Equation 43]

$$\begin{aligned} X_b(lT_c) &= \sum_{i=0}^{N_c-1} [y_v(lT_c - iT_c)] \rho_{p_0}(N_cT_c - iT_c) \\ &= \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_b(m) [q_v^{(p_0)}(lT_c - mT)] + [X_b^{(p_0)}(lT_c)] \end{aligned}$$

[0098] It is here and is [Equation 44].

$$[q_v^{(p_0)}(lT_c)] = \sum_{i=0}^{N_c-1} [g_v(lT_c - iT_c)] c_{v_{p_0}}(i)$$

[Equation 45]

$$[X_b^{(p_0)}(lT_c)] = \sum_{i=0}^{N_c-1} [n_v(lT_c - iT_c)] c_{b_{p_0}}(i)$$

[0099] Like formulation of several 19 vector, lT_c is expressed with $kT - jT_c$ (here, it is $0 \leq j \leq N_c - 1$), and the signal vector of the sub digital disposal circuit 16-1 thru/or the symbol level in 16- N_c is defined like a degree type.

[0100]

[Equation 46] $[X_c(kT)] = [[X_b(kT)]^T, \dots, [X_b(kT - (N_c - 1)T_c)]^T]^T$ [0101] By several 43, a degree type can show several 46.

[0102]

[Equation 47]

$$[X_c(kT)] = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_b(m) [q_c^{(p_0)}(kT - mT)] + [X_c^{(p_0)}(kT)]$$

[0103] It is here and is [Equation 48].

$$[q_c^{(p_0)}(kT)] = [[q_v^{(p_0)}(kT)]^T, \dots, [q_v^{(p_0)}(kT - (N_c - 1)T_c)]^T]^T$$

[Equation 49]

$$[X_c^{(p_0)}(kT)] = [[X_b^{(p_0)}(kT)]^T, \dots, [X_b^{(p_0)}(kT - (N_c - 1)T_c)]^T]^T$$

[0104] From assumption 3, it is the wave signal of a $J \times N_c$ dimension.

[Equation 50]

$$[q_c^{(p_0)}(kT)]$$

It is known that ***** is restricted. Therefore, several 47 can be expressed like a degree type.

[0105]

[Equation 51]

$$[X_c(kT)] = \sum_{d=0}^{D_{p0}} s_{p0}(k-d) [q_{c_{p0}}(dT)] + \sum_{\substack{p=1 \\ p \neq p0}}^P \sum_{d=0}^{D_p} s_p(k-d) [q_{c_p}(dT)] + [X_{c_n}(kT)]$$

[0106] It is here and is [Equation 52].

D_{p0}

It is the die length of the symbol level of ** and a p0 position user-terminal channel. Several 51 shows that the 2nd term contains the cross-correlation component which the signal from the user terminal which is not desirable piled up to the 1st term of the right-hand side including all the components of the signal from a desired user terminal. The above-mentioned cross-correlation component must be oppressed. Based on several 51, ecad processing of symbol level can be performed like a degree type.

[0107]

[Equation 53]

$$z_c(k) = \sum_{b=0}^{M-1} [w_{1b}]^T [X_c((k-1+b)T)] = [W]^T [Y_c(k)]$$

[0108] Here, the signal vector $[Y_c(k)]$ and weighting-factor vector $[W]$ of a $J \times N_c \times M$ dimension are expressed with a degree type.

[0109]

[Equation 54] $[Y_c(k)] = [[X_c(kT)]^T, \dots, [X_c(kT-(M-1)T)]^T]^T$ [0110]

[Equation 55]

$[W] = [[w_0]^T, \dots, [w_{M-1}]^T]$

[Equation 56] $[w_m] = [w_{m1}, w_{m2}, \dots, w_{mN_c}]^T$ (ma=1, 2, ..., M)

[0111] Several 56 is a weighting factor by which multiplication is carried out to a signal vector $[Y_c(kT)]$, and the weighting-factor vector $[W]$ of several 55 is generated from all those weighting factors. The transversal filter circuit 23-1 thru/or the number M of taps of 23-Nc are the die length [several 57] of the symbol level of a p0 position user-terminal channel.

D_{p0}

It is chosen according to the number of user terminals of the same channel, and performance requirements. Based on MMSE criteria, several 58 [i.e.,], the optimal weighting-factor vector is acquired like several 59 like the processing in the case of TDMA.

[0112]

[Equation 58]

$$\min_{[W]} E |s_{p0}(k-v) - z_c(k)|^2$$

[Equation 59]

$$[W_{p0}]^* = [R_c]^{-1} [\gamma_{p0}(v)]$$

[0113] Here, the correlation vector $[\gamma_{p0}(v)]$ of the temporal phase Seki matrix $[R_c]$ of a signal vector, and a study sequence signal and a signal vector is expressed with a degree type, respectively.

[0114]

[Equation 60]

$$[RC]=E\{[YC(k)][YC(k)]^H\}$$

[Equation 61]

$$[\gamma_{p_0}(v)] = E \{ s_{p_0}^*(k-v) [Y_C(k)] \}$$

[0115] It is here and is [Equation 62].

$$s_{p_0}(k)$$

The study sequence signal (study symbol sequence) of a ** p0 position user terminal is shown. The error of the signal sbp0 (k-v) with which only the predetermined time delay v was delayed in the study sequence signal, and the processing signal zC (k) is minimized, and adaptive control of the adaptive control mold controller 7 is carried out by calculating a weighting-factor vector [W] so that the control device of an array antenna may output the best engine performance so that clearly from several 58. The adaptive control mold controller 7 outputs the weighting-factor vector [W] searched for by several 59 thru/or 61 to the time domain signal-processing section 4, in the transversal filter circuit 23-1 of a JxNc individual thru/or 23-Nc, multiplication is carried out to a signal vector [YC], the signal of a multiplication result is added in an adder 24, and a weighting-factor vector [W] is outputted from the sub digital disposal circuit 16-1 thru/or 16-Nc. The adaptive control mold controller 7 makes the residuum power of processing signal z (k) outputted minimize by repeating above-mentioned processing and making it converge based on the error signal of the processing signal z (k) and the study sequence signal which are outputted. The minimum residuum power when having the set of a reactance value with which the variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 were given like several 34 is expressed like a degree type.

[0116]

[Equation 63]

$$\begin{aligned} \sigma_{C_MMSE}^2(v) \Big|_{x_1, \dots, x_6} &= E \{ |s_{p_0}(k-v) - z_C(m)|^2 \\ &= E \{ |s_{p_0}(k-v)|^2 - [W_{p_0}]^T [R_C] [W_{p_0}]^* \\ &= E \{ |s_{p_0}(k)|^2 - [\gamma_{p_0}(v)]^H [R_C]^{-1} [\gamma_{p_0}(v)] \} \end{aligned}$$

[0117] As explained above, while the adaptive control mold controller 7 carries out adaptation processing of the request signal in a time domain in the time domain signal-processing section 4, it can process a request signal in a space field in array antenna equipment 100 (space-time concomitant use ecad filtering). The above-mentioned content shows that it may be included [in TDMA] by the approach that both formulation of processing is the same also in CDMA, when the variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 have the set of a predetermined reactance value. Hereafter, processing signal z (m) expresses the processing output in the case of both TDMA and CDMA, and this is expressed with a degree type.

[0118]

$$[Equation 64] \quad z(m)=[W]^T[Y(m)]$$

[0119] As mentioned above, a signal vector [Y (m)] is the function of a variable reactive element 12-1 thru/or the reactance value of 12-6 again, and ecad filtering which uses together processing between the optimal space-time to the signal of the p-th user terminal is written like minimizing several 65 simultaneously with reference to a weighting-factor vector [W] and the reactance values X1, X2, ..., X6, several 66 [i.e.,].

[0120]

[Equation 65]

$$\text{sigmatotal2}=E\{s_{bp}(m-v)-z(m)\}^2 \quad [Equation 66]$$

$$(X_{h_1}, \dots, X_{h_6}, W_h)_{opt}$$

$$= \arg \min_{x_1, \dots, x_6, [W]} E \{ |s_{p_0}(m-v) - [W]^T [Y(m)]|^2 \}$$

[0121] Under the set of the given data, it is known that the solution method of the optimal

weighting-factor vector and reactance value of several 66 is activation of the global retrieval on the associated field. However, it is impossible to use actually the global retrieval which such time amount requires. Therefore, it is necessary to consider a certain alternate method.

[0122] The most fundamental approach also in the optimization approach is the alternative searching method (alternative search) based on a coordinate, and is applied with the result sufficient for many applications. On this application descriptions, several 66 optimization problem is solved using the alternative searching method based on this coordinate.

[0123] Subsequently, the renewal algorithm of a block for performing actually the above-mentioned space-time concomitant use ecad filtering is explained. In the above explanation, the procedure which calculates a weighting-factor vector [W] was explained, having assumed that it had the value to which the variable reactive element 12-1 thru/or the reactance value of 12-6 were given beforehand. The following parts of this application description explain adaptive control processing of the reactance value of the array antenna equipment 100 performed by the adaptive control mold controller 4 based on the flow chart of drawing 6. In the point of the alternative retrieval based on a coordinate, several 66 optimization problem is formulized from two phases of procedures in which views differ. First, it assumes that the reactance values X1, X2, ..., X6 are being fixed as explanation of a general procedure, and the optimal weighting-factor vector is dispelled. This is shown in several 31 or several 59. Therefore, several 66 becomes like a degree type.

[0124]

[Equation 67]

$(X_{h_1}, \dots, X_{h_6})_{opt}$

$$\begin{aligned} &= \arg \min_{x_1, \dots, x_6} E \left\{ |s_{bp}(m-v) - [W_{opt}]^T [Y(m)]|^2 \right\} \\ &= \arg \min_{x_1, \dots, x_6} \left\{ E \left\{ |s_{bp}(m)|^2 \right\} - [r(v)]^H [R]^{-1} [r(v)] \right\} \\ &= \arg \min_{x_1, \dots, x_6} \left\{ \sigma_p^2 - [r(v)]^H [R]^{-1} [r(v)] \right\} \end{aligned}$$

[0125] It is here and is [Equation 68]. $[W_{opt}]^* = [R]^{-1} [r(v)]$

[Equation 69] $[R] = E\{[Y(m)][Y(m)]^H\}$

[Equation 70]

$[r(v)] = E[s_{bp}^*(m-v)[Y(m)]]$

[0126] The time delay v of a study sequence signal is beforehand determined by the adaptive control mold controller 7 so that the error of the study sequence signal with which only time amount v was delayed, and processing signal z(t) may be minimized based on several 30 and several 58 criteria. Moreover, a degree type is the power of the symbol signal of the p-th user terminal.

[0127]

[Equation 71] $\text{sigmap2} = E[s_{bp}(m)]^2$ [0128] Subsequently, the procedure of the renewal of a block which solves an optimization problem is explained more concretely. The optimal reactance value is looked for according to the die length to which received data were restricted, and several 67, and the correlation vector [r(v)] of the temporal phase Seki matrix [R] of a signal vector, and a study sequence signal and a signal vector is presumed by it. That is, the following two operations are performed.

[0129]

[Equation 72]

$$[R_h] = \frac{1}{N_t} \sum_{m=m_k}^{m_k+N_t-1} [Y(m)] [Y(m)]^H \quad |_{x_1, \dots, x_6}$$

[Equation 73]

$$[r_h(v)] = \frac{1}{N_t} \sum_{m=m_k}^{m_k+N_t-1} s_{bp}^*(m-v) [Y(m)] \quad |_{x_1, \dots, x_6}$$

[0130] here $m_k = N_t l$ and $l = 0, 1, \dots, M_t$ and M_t shows the number of data blocks required for convergence. Under the set of the given reactance value, the number N_t of symbols

is chosen by the activity of the 2nd [an average of] power (LMS) algorithm of the minimum so that it can be completed as a steady state by the weighting-factor vector [W] within the symbol period of N_t individual. A formula, such as relating to several 7, several 9, several 13, several 26, several 54, and these, shows that a signal vector [Y (m)] is not the function with which the reactance values X_1, X_2, \dots, X_6 were expressed explicitly. that is, the term [r (v)] [R] H of the secondary format of a correlation vector — it means that -1 [r (v)] is the implicit function of the reactance values X_1, X_2, \dots, X_6 .

[0131] the term [r (v)] [R] H an updating algorithm suitable in order to discover the optimal reactance ($X_{h1}, X_{h2}, \dots, X_{h6}$) opt to an implicit function is the maximum dive algorithm for updating a reactance, and concerning the reactance values X_1, X_2, \dots, X_6 — the gradient vector of -1 [r (v)] must be evaluated. Term [r (v)] [R] H — since -1 [r (v)] is evaluated according to the given data block to which the length was limited — the renewal algorithm of a block — Term [r (v)] [R] H — it is constituted about the estimate based on the data block of -1 [r (v)]. A degree type is assumed as a criterion function.

[0132]

[Equation 74]

$$[f_h(X_1, X_2, \dots, X_6)] \\ = \sigma_{h,p}^2 - [r_h(v)]^H [R_h]^{-1} [r_h(v)] \big|_{X_1, \dots, X_6}$$

[0133] Here, the 2nd term of the right-hand side makes a variable the reactance values X_1, \dots, X_6 . $\sigma_{h,p}^2$ is the power by which the symbol signal of the p -th user terminal was evaluated. In the context of the maximum dive algorithm (see the conventional technical reference 6 "R.A.Monzingo et al., "Introduction to Adaptive Arrays", John Wiley & Sons, Inc., and 1980"), the following updating equations for performing adaptive control processing to a reactance value are obtained from several 74.

[0134]

[Equation 75]

$$X_v^{(k+1)} = X_v^{(k)} - \alpha \nabla_{X_v} f_h(X_v) \big|_{X_v = X_v^{(k)}}$$

[0135] It is here and is [Equation 76]. $X_v = [X_1, X_2, \dots, X_6]^T$ — [Equation 77] $X_v(k) = [X_1(k), X_2(k), \dots, X_6(k)]^T$ [0136]

[Equation 78]

$$\nabla_{X_v} f_h(X_v) = [\nabla_{X_1} f_h(X_1, \dots, X_6), \dots, \nabla_{X_6} f_h(X_1, \dots, X_6)]^T$$

[Equation 79]

$$\nabla_{X_i} f_h(X_1, \dots, X_i, \dots, X_6) \\ \approx [f_h(X_1, \dots, X_i + \Delta X, \dots, X_6) - f_h(X_1, \dots, X_i, \dots, X_6)] / \Delta X$$

[0137] Here, alpha is a step size for updating, for example, takes the value of 1000 thru/or 2000.

[0138] The procedure of renewal of the reactance value by the adaptive control processing illustrated by drawing 6 is performed as follows. In step S1, the number epsilon which controls the number of occurrence of renewal of a reactance value is set up, and the count k of updating of a reactance is further set to 0 as an initial state. Next, in step S2, initial value [of a reactance value vector] $X_v(0) = (X_1(0), X_2(0), \dots, X_6(0))$ is set up, and subsequently, in step S3, the reactance value signal corresponding to the reactance value vector $X_v(k)$ is generated, and it is outputted and set as a variable reactive element 12-1 thru/or 12-6. For example, the initial value of a reactance value vector can be set as zero vector, and an updating algorithm can be started from an omnidirectional beam pattern (see drawing 9). And in step S4, based on an input-signal vector [Y (m)] and the study sequence signal vector $s_{bp}(m)$, a matrix of correlation [R] and a correlation vector [r (v)] are calculated, the optimal weight vector [Wopt] is calculated using several 68 using several 72 and several 73, and it outputs to the time domain signal-processing section 4. Subsequently, in step S5, the inclination of a criterion function f_h is calculated using several 78 and several 79, and the reactance value vector $X_v(k+1)$ is further calculated from the reactance value vector $X_v(k)$ by several 75. Subsequently, in step S6, it is

determined whether the inequality of a degree type is materialized.

[0139]

[Equation 80]

$|fh(X_v(k)) - fh(X_v(k+1))| \leq \epsilon$ [0140] Here, ϵ is a repetitive threshold, when several 80 inequality is materialized in step S6, while progressing to step S8, when not materialized, it progresses to step S7, only 1 increments k , and (NO) returns to step S3. In step S8, the reactance value signal corresponding to the reactance value vector $X_v(k+1)$ is generated, it is outputted and set as a variable reactive element 12-1 thru/or 12-6, and adaptive control processing is ended.

[0141] If ecad filtering between space-time based on the ESUPA antenna explained above is used, the steering of the beam of array antenna equipment 100 can be carried out in the arrival direction of a request signal, a spatial interference can be oppressed, and a time interference of ISI contained by the time domain signal-processing section 4 in an input signal can be oppressed.

[0142]

[Example] this invention persons performed computer simulation about the control unit of the array antenna of drawing 1, and confirmed the effectiveness of ecad filtering between space-time by using the control unit of this array antenna. In this simulation, it is a premises network system, and the signal of the DS-CDMA user terminal of the 15 same channels exists, and let a user 1 be a request user. The code die length of the signal of all user terminals is set as 127. The Gaussian distribution of AOA of the path of the signal of each user terminal set up so that the signal of each user terminal might have six multi-pass waves and an include angle might have spacing of 8 times mutually is carried out, and those time delay assumes that it is a thing according to the exponential distribution which have the delay which spread 1.1 symbol period. The propagation loss of a multi-pass wave shall be included by SNR of the array component of the direct wave of the signal of a user terminal. In this case, SNR to the signal of a user's 1 terminal is assumed to be -10dB, and SNR of the signal of all other user terminals changes at random by -26.55dB thru/or -4.76dB. Moreover, all user terminals shall be uniformly distributed in the visual field of array antenna equipment 100. A table 2 has indicated the detailed parameter of the signal a user's 1 terminal.

[0143]

[A table 2]

	Path	theta (degree)	tau (symbol)	xi (propagation loss)
1	12.30	0	-0.9669+0.2550j	21.50 0.04 0.7437-
2	0.3081j	3 20.20	0.05 -0.5206-0.5100j	4 8.70 0.12 -0.3081-0.4569j
3	5 23.40	0.33 -0.1806+0.3931j	6 13.20	0.47-0.1912+0.1275j

[0144] Here, the over sampling technique multiplier was set up with $J=1$, and the number of taps of a transversal filter circuit is set up with $M=1$. As mentioned above, a variable reactive element 12-1 thru/or 12-6 are [Equation 81]. When it has the set of a given reactance value like $X_v = [-53, -136, 61, 51 \text{ and } 59, -146]$ T, N_t is the measurement size of symbol level and can converge the weighting-factor vector of several 64 to the steady state of several 68 with the conventional LMS algorithm based on this.

[0145] Drawing 7 is a graph showing an example of the convergence curve of the residuum power for determining the measurement size N_t of the symbol level converged on a steady state in adaptive control processing of drawing 6. It turns out that a weighting-factor vector is converged to the steady state within the symbol period of about 200 so that clearly from drawing 7. This means that number $N_t=200$ of a symbol period are employable. Repeatedly [of the reactance of this simulation], $N_t=200$ are adopted as the number of symbol periods. In order to show the behavior in the case of convergence of an updating algorithm, data block number $M_t=7 \times 20$ and the repetitive threshold $\epsilon=1 \times 10^{-10}$ of several 81 sake are set up.

[0146] drawing 8 — drawing 6 — adaptive control — processing — setting — a data block — updating — a sake — a criterion function — a value — convergence — a curve — an example — being shown — a graph — it is — drawing 9 — drawing 6 — adaptive control — processing —

-- having performed -- the time -- a reactance -- a value -- a vector -- initial value -- X_v -- (- zero --) -- = (0, 0, 0, 0, 0, 0) -- corresponding -- an array antenna -- equipment -- 100 -- a beam -- a pattern -- a graph -- it is . It starts from the initial value X_v of this reactance value vector (0), adaptive control processing of drawing 6 is performed and updated, and a beam pattern in case the counts k of updating are 2 times, 4 times, 9 times, 13 times, and 19 times, respectively is shown in drawing 10 thru/or drawing 14 . All the multi-pass waves of the signal of a desired user terminal are included with a steady state pattern, and are strengthened, and it turns out that the multi-pass wave of the signal of the user terminal which is not desirable is mitigated with the lower order lobe of a steady state pattern so that clearly from a table 2 and drawing 14 . It is clear from these two drawings by carrying out beam pattern formation of array antenna equipment 100, and time equalization of the input signal in the time domain signal-processing section collectively that ecad filtering between space-time is effectively realizable. [0147]

[Effect of the Invention] As explained in full detail above, according to this invention, the radio signal received in the ESUPA antenna is divided into the sub signal of two or more time domains. By adding, after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, perform signal processing of a time domain and it outputs as a processing signal. Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the above-mentioned time domain signal-processing means so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal was calculated, and it constituted so that the value of the above-mentioned criterion function might serve as min and the reactance value of each above-mentioned variable reactive element might be calculated and set up. Therefore, as compared with the conventional technique, it has an easy configuration, and a manufacturing cost is cheap and space-time adaptation processing which is for an ESUPA antenna can be performed. Moreover, a cochannel-interference signal can be spatially controlled on an effective target by accommodative beam pattern formation, and a symbol interference signal can be controlled on an effective target by ecad equalization based on a time wave.

[Translation done.]

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TECHNICAL FIELD

[Field of the Invention] About the control unit and the control approach of the array antenna to which the directional characteristics of the array antenna equipment which consists of two or more antenna elements can be changed, this invention is electronics control wave director array antenna equipment (it is called an ESUPA antenna below Electronically Steerable Passive Array Radiator (ESPAR) Antenna;) to which directional characteristics can be changed especially accommodative, and relates to the control unit and the control approach of the array antenna which can process a TDMA input signal or a CDMA input signal.

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PRIOR ART

[Description of the Prior Art] An ESUPA antenna for example "The conventional technical reference 1 T.Ohira and "Microwave signalprocessing and devices for adaptive beamforming and "IEEE Antenna and Propagation society It is proposed in International Symposium vol.two, pp.583-586, Salt LakeCity, Utah July 16-21, and the patent application of 2000" and Japanese Patent Application No. No. 194487 [11 to]. This ESUPA antenna can change the directional characteristics of the above-mentioned array antenna by having the array antenna which consists of the driven element by which a radio signal is transmitted and received, at least one parasitic element by which only predetermined spacing is left and prepared from this driven element, and a radio signal is not transmitted and received, and the variable reactive element connected to this parasitic element, and changing the reactance value of the above-mentioned variable reactive element.

[0003] Moreover, multi-pass propagation and cochannel interference (CCI) exist in radiocommunication as two problems which have an adverse effect on a wireless system. These problems appear as the interference (ISI) between symbols resulting from the reuse of the frequency in a TDMA wireless system and cochannel interference, or multiuser access interference (MAI) in a CDMA wireless system, respectively.

[0004] In order to solve the above trouble, the ecad processing (STAP) between space-time (refer to the conventional technical reference 2 "J.Paulraj et al. and "Space-time processing for wireless communications" IEEE Signal Processing Magazine, Vol.14, No.6, pp.49-83, and November 1997") is proposed, and it is thought that this processing demonstrates the engine performance which stood high in control of both ISI and CCI. Recently, the approach of the ecad processing (STAP) between space-time is proposed and analyzed to TDMA or a direct diffusion (sequence) CDMA (DS-CDMA) radio communications system.

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EFFECT OF THE INVENTION

[Effect of the Invention] As explained in full detail above, according to this invention, the radio signal received in the ESUPA antenna is divided into the sub signal of two or more time domains. By adding, after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, perform signal processing of a time domain and it outputs as a processing signal. Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the above-mentioned time domain signal-processing means so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal was calculated, and it constituted so that the value of the above-mentioned criterion function might serve as min and the reactance value of each above-mentioned variable reactive element might be calculated and set up. Therefore, as compared with the conventional technique, it has an easy configuration, and a manufacturing cost is cheap and space-time adaptation processing which is for an ESUPA antenna can be performed. Moreover, a cochannel-interference signal can be spatially controlled on an effective target by accommodative beam pattern formation, and a symbol interference signal can be controlled on an effective target by ecad equalization based on a time wave.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, implementation of the antenna array channel of a STAP system is complicated, and since it is high cost, it is difficult [it] to apply these widely actually especially in the situation that it is supposed like a wireless premises network system or a user-terminal machine that it is cost a very important element. This means that it is practical Important to develop the STAP system of cost easy a configuration and lower.

[0006] The object of this invention solves the above trouble, and has an easy configuration as compared with the conventional technique, and its manufacturing cost is cheap, and it is in offering the control unit and the control approach of an array antenna that space-time adaptation processing which is for an ESUPA antenna can be performed.

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MEANS

[Means for Solving the Problem] A radiating element for the control unit of the array antenna concerning this invention to receive a radio signal, Two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control unit of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed The radio signal received in the above-mentioned array antenna is divided into the sub signal of two or more time domains. A time domain signal-processing means to perform signal processing of a time domain and to output as a processing signal by adding after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the above-mentioned time domain signal-processing means so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal is calculated, and it is characterized by having the ecad control means which calculates and sets up the reactance value of each above-mentioned variable reactive element so that the value of the above-mentioned criterion function may serve as min.

[0008] Moreover, the control approach of the array antenna concerning this invention The radiating element for receiving a radio signal, and two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control approach of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed The radio signal received in the above-mentioned array antenna is divided into the sub signal of two or more time domains. The step which performs signal processing of a time domain and is outputted as a processing signal by adding after carrying out the multiplication of the predetermined weighting factor to two or more sub signals which carried out [above-mentioned] division, respectively, Based on a predetermined study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs for signal processing of the above-mentioned time domain so that the error signal of the above-mentioned processing signal and the above-mentioned study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal is calculated, and it is characterized by including the step which calculates and sets up the reactance value of each above-mentioned variable reactive element so that the value of the above-mentioned criterion function may serve as min.

[0009]

[Embodiment of the Invention] Unlike the null formed with the conventional ecad algorithm, or the beam beforehand formed in advance of signal processing (formed in advance before), by this invention, the control unit and the control approach of an array antenna that a strange good beam pattern and the equalizer of a time domain can be used together, and ecad filtering between space-time can be realized are offered. It is thought that an ESUPA antenna has the capacity which forms a beam spatially towards a desired signal at the minimum cost. In this invention, the control unit and the control approach of an array antenna for realizing ecad filtering (STAF) between space-time using an ESUPA antenna for TDMA or a CDMA signal wave form are proposed.

[0010] Hereafter, the operation gestalt of this invention is explained with reference to a drawing.

[0011] Drawing 1 is the block diagram of the control device of the array antenna of the operation gestalt concerning this invention. The control unit of the array antenna of this operation gestalt is characterized by have the array antenna equipment 100 which consisted of ESUPA antennas of the conventional technique which is equip with one driven element A0, six parasitic elements A1, or A6, and becomes, the time domain signal processing section 4 which processes the radio signal received with the above-mentioned array antenna equipment 100, and the adaptive control mold controller 7 which controls them, as show in drawing 1.

[0012] drawing 1 — setting — array antenna equipment 100 — touch-down — it consists of a driven element A0 prepared on the conductor 11 and a parasitic element A1 thru/or A6, and the driven element A0 is arranged as surrounded in six parasitic elements A1 prepared on the periphery of a radius r thru/or A6. Preferably, on the periphery of the above-mentioned radius r , each parasitic element A1 thru/or A6 keep regular intervals mutual, and is prepared. Each driven element A0 and a parasitic element A1 thru/or the die length of A6 are constituted so that it may become the abbreviation $1/4$ of the wavelength λ of a request wave, and the above-mentioned radius r is constituted so that it may become $\lambda/4$. The feeding point of a driven element A0 is connected to a low noise amplifier (LNA) 1 through a coaxial cable 9, and a parasitic element A1 thru/or A6 are connected to a variable reactive element 12-1 thru/or 12-6, respectively, and these variable reactive elements 12-1 thru/or the reactance value of 12-6 are set up by the reactance value signal from the adaptive control mold controller 7.

[0013] Drawing 2 is drawing of longitudinal section of array antenna equipment 100. a driven element A0 — touch-down — it insulates with a conductor 11 electrically — having — each parasitic element A0 thru/or A6 — a variable reactive element 12-1 thru/or 12-6 — minding — touch-down — it is grounded in RF to a conductor 11. If a variable reactive element 12-1 thru/or actuation of 12-6 are explained, when the die length of a radiating element A0, a parasitic element A1, or the longitudinal direction of A6 is substantially the same (for example, when a variable reactive element 12-1 has inductance nature (L nature)), a variable reactive element 12-1 serves as an extension coil, and a parasitic element A1 thru/or the electric merit of A6 will become long as compared with a driven element A0, and it will work as a reflector, for example. On the other hand, when a variable reactive element 12-1 has capacitance nature (C nature), a variable reactive element 12-1 serves as a loading condenser, and the electric merit of a parasitic element A1 becomes short as compared with a driven element A0, and it works as the wave director.

[0014] Therefore, in the array antenna equipment 100 of drawing 1, the flat-surface directivity property of array antenna equipment 100 can be changed by changing the variable reactive element 12-1 thru/or the reactance value of 12-6 connected to each parasitic element A1 thru/or A6.

[0015] In the control unit of the array antenna of drawing 1, array antenna equipment 100 receives a radio signal, through a coaxial cable 9, the signal by which reception was carried out [above-mentioned] is inputted into a low noise amplifier (LNA) 1, and is amplified, and, subsequently a down converter (D/C) 2 carries out low-pass conversion of the amplified signal at the signal (IF signal) of a predetermined intermediate frequency. Furthermore, A/D converter 3 carries out A/D conversion of the analog signal by which low-pass conversion was carried out to a digital signal, and outputs the digital signal by which A/D conversion was carried out to the

time domain signal-processing section 4. Subsequently, the time domain signal-processing section 4 divides into the sub signal of two or more time domains radio-signal $y(t)$ received by array antenna equipment 100. By adding, after outputting the signal vector $[Y]$ which consists of two or more divided sub signals to the adaptive control mold controller 7 and carrying out the multiplication of the predetermined weighting factor to two or more divided sub signals, respectively, signal processing of a time domain is performed and it outputs as processing signal $z(t)$. And the adaptive-control mold controller 7 calculates an error signal by subtracting above-mentioned processing signal $z(t)$ from the study sequence signal generated by the study sequence signal generator 6, and further, the adaptive-control mold controller 7 performs adaptive-control processing by calculating the optimal weighting-factor vector $[W]$, and outputting to the time-domain signal-processing section 4 so that an error signal may serve as min based on the above-mentioned study sequence signal and a signal vector $[Y]$. Specifically here the adaptive control mold controller 7 Based on a study sequence signal and each above-mentioned sub signal, calculate the above-mentioned weighting factor and it outputs to the time domain signal-processing section 4 so that the error signal of processing signal $z(t)$ and a study sequence signal may serve as min. The gradient vector of the predetermined criterion function which shows the value corresponding to the above-mentioned error signal is calculated, and each variable reactive element 12-1 thru/or the reactance value of 12-6 are calculated and set up so that the value of the above-mentioned criterion function may serve as min.

[0016] According to the digital data signal of a predetermined symbol rate including the same study sequence signal as the predetermined study sequence signal generated with the study sequence signal generator 6, the sending station which transmits the radio signal received with an array antenna 100 modulates the carrier signal of a radio frequency using digital modulation methods, such as QPSK, or the direct diffuse-spectrum diffusion becoming [irregular] method, carries out power amplification of the modulating signal concerned, and transmits it towards the array antenna equipment 100 of a receiving station. In the operation gestalt concerning this invention, before performing data communication, the radio signal which includes a study sequence signal towards a receiving station from a sending station is transmitted, and adaptive control processing by the adaptive control mold controller 7 is performed in a receiving station.

[0017] Next, with reference to drawing 3 thru/or drawing 5, the time domain signal-processing section 4 of drawing 1 is explained more to a detail. Drawing 3 is the block diagram of the time domain signal-processing section 4-1 for TDMA which is the 1st operation gestalt of the time domain signal-processing section 4. two or more [(shift register SR) 13-1 thru/or 13-(J-1) of two or more (J-1) individuals to which cascade connection of the time domain signal-processing section 4-1 for TDMA was carried out mutually, and] — two or more [J down samplers 14-1 thru/or 14-J, and] — it has J transversal filter circuits 23-1 thru/or 23-J, and an adder 17, and is constituted. The above-mentioned shift register (SR) 13-1 thru/or 13-(J-1) delay for it and output only 1 symbol period for an input signal based on the clock inputted, respectively. The multiplication of the weighting-factor data Dw_1 which outputted the signal data Dx_1 divided into the sub signal of two or more time delay thru/or Dx_J to the adaptive control mold controller 7, and were calculated by the adaptive control mold controller 7 for the operation of a weighting factor thru/or the Dw_J is carried out to each signal into which it was inputted, and the transversal filter circuit 23-1 thru/or 23-J output it to it.

[0018] Input-signal $y(t)$ outputted from A/D converter 3 of drawing 1 is inputted into a shift register 13-1 as the down sampler 14-1. The down sampler 14-1 carries out the down sampling of the inputted input-signal $y(t)$ with a sampling frequency $1/J$ time the sampling frequency of A/D converter 3, and outputs the signal after processing to an adder 17 through the transversal filter circuit 23-1 which carries out the detail after-mentioned. The signal outputted from the shift register 13-1 is inputted into a shift register 13-2 as the down sampler 14-2. The down sampler 14-2 carries out the down sampling of the inputted signal with a sampling frequency $1/J$ time the sampling frequency of A/D converter 3, and outputs the signal after processing to an adder 17 through the transversal filter circuit 23-2. The signal outputted from shift register 13-j ($j=2, 3, \dots, J-1$) is outputted to down sampler 14-(j+1) and shift register 13-(j+1) like the following. Down sampler 14-(j+1) carries out the down sampling of the inputted signal with a

sampling frequency $1/J$ time the sampling frequency of A/D converter 3, and outputs the signal after processing to an adder 17 through transversal filter circuit 23- $(j+1)$. two or more [furthermore, / into which the adder 17 was inputted] — J signals are added and the signal of an addition result is outputted as processing signal $z(t)$.

[0019] Drawing 4 is the block diagram showing the configuration of the transversal filter circuit 23-1 of drawing 3. With the delay circuit 25-1 of two or more $(M-1)$ individuals thru/or 25- $(M-1)$ to which only $1/4$ of one symbol thru/or the time amount of $1/2$ were delayed, respectively, and cascade connection was mutually carried out, the transversal filter circuit 23-1 is equipped with two or more M multipliers 26-1 thru/or 26- M , and adders 27, and the signal inputted by passing the down sampler 22-1 is constituted. The signal inputted into the transversal filter circuit 23-1 it outputs to the adaptive control mold controller 7 as data of a sub signal — having — and weighting-factor w , while being outputted to an adder 27 through the multiplier 26-1 which has the multiplication multiplier of 1 and 1. It is outputted to an adder 27 through the delay circuit 25-1 of an individual $(M-1)$ thru/or 25- $(M-1)$ by which cascade connection was carried out mutually, and multiplier 26- M which has the multiplication multiplier of weighting factors w_1 and M . Here, the suffix of weighting-factor w expresses the transversal filter circuit 23-1 the serial number 1 of 23- J thru/or J with the 1st suffix, and expresses each above-mentioned transversal filter circuit 23-1 the serial number 1 of the multiplier in 23- J thru/or M with the 2nd suffix. moreover — while the signal outputted from a delay circuit 25-1 is outputted to the adaptive control mold controller 7 — weighting-factor w — while the signal which is outputted to an adder 27 through the multiplier 26-2 which has the multiplication multiplier of 1 and 2, and is further outputted from a delay circuit 25-2 is outputted to the adaptive control mold controller 7 — weighting-factor w — it is outputted to an adder 17 through the multiplier 26-3 which has the multiplication multiplier of 1 and 3. Like the following, the signal outputted from delay circuit 26- m_a ($m_a=3, \dots, M-1$) is outputted to an adder 27 through multiplier 26- (m_a+1) which has a weighting factor w_1 and the multiplication multiplier of m_a+1 while it is outputted to the adaptive control mold controller 7. And an adder 27 adds M signals inputted and outputs the signal of an addition result to an adder 17.

[0020] Moreover, with the delay circuit of two or more $(M-1)$ individuals by which cascade connection was carried out mutually, the transversal filter circuit 23-2 of drawing 3 thru/or 23- J are equipped with two or more M multipliers and adders, and is constituted like the transversal filter circuit 23-1. The time domain signal-processing section 4 compounds the signal data Dx_1 outputted from each transversal filter circuit 23-1 thru/or 23- J thru/or Dx_J to a signal vector $[Y]$, and outputs it to the adaptive control mold controller 7. Moreover, the time domain signal-processing section 4 decomposes into the weighting-factor data Dw_1 thru/or Dw_J , and carries out the multiplication of the weighting-factor vector $[W]$ inputted from the adaptive control mold controller 7 to the signal inputted there in each transversal filter circuit 23-1 thru/or 23- J .

[0021] Drawing 5 is a block diagram of the time domain signal-processing section 4-2 for CDMA concerning the 2nd operation gestalt of the time domain signal-processing section 4 which replaces the 1st operation gestalt of drawing 3. In this operation gestalt, instead of the transversal filter circuit 23-1 concerning the 1st operation gestalt thru/or 23- J They are J matched filters (it is also called a matched filter.) two or more. [matched filter;] It is characterized by having 15-1 thru/or 15- J , and the sub digital disposal circuit 16-1 thru/or 16- J connected to each above-mentioned matched filter 15-1 thru/or 15- J . The other configuration is the same as that of the time domain signal-processing section 4-1 for TDMA of the 1st operation gestalt, and the detailed explanation is omitted.

[0022] In drawing 5, $J-1$ shift register 13-1 thru/or 13- $(J-1)$ by which cascade connection was carried out mutually, and J down samplers 14-1 thru/or 14- J is constituted like the time domain signal-processing section 4-1 for TDMA. The signal outputted from the down sampler 14-1 is inputted into a matched filter 15-1, and a matched filter 15-1 detects the request wave signal buried into white noise with the greatest SN ratio based on the data D_{cp} of the diffusion sign of the user terminal of a request wave into which the signal by which the down sampling was carried out is inputted from the controller (not shown) of a receiver, and, specifically, outputs a pulse signal for every period of a diffusion sign. Subsequently, the signal from a matched filter

15-1 is outputted to an adder 17 through the sub digital disposal circuit 16-1 which carries out the detail after-mentioned. Moreover, the signal outputted from the down sampler 14-2 is outputted to an adder 17 through a matched filter 15-2 and the sub digital disposal circuit 16-2. Each matched filter 15-j ($j=3, 4, \dots, J$) outputs like the following the signal outputted from down sampler 14-fa to an adder 17 through sub digital-disposal-circuit 16-j.

[0023] Subsequently, the detail configuration of the sub digital disposal circuit 16-1 of drawing 5 is explained. With the delay circuit 21-1 of two or more (N_c-1) individuals thru/or 21- (N_c-1) by which cascade connection was carried out by having the predetermined time delay T_c , respectively, the sub digital disposal circuit 16-1 is equipped with two or more transversal filter circuits 23-1 of N_c individual thru/or 23- N_c (s), and adders 24 with the down sampler 22-1 of N_c individual thru/or 22- N_c , and are constituted. [two or more] The signal outputted from the matched filter 15-1 is outputted to a delay circuit 21-1 and the down sampler 22-1. The down sampler 22-1 carries out the down sampling of the inputted signal with a sampling frequency $1/N_c$ time the sampling frequency [the down sampler 14-1 thru/or] of 14-J, and outputs the signal after processing to an adder 24 through the transversal filter circuit 23-1.

[0024] The transversal filter circuit 23-1 thru/or 23- N_c output the signal data $Dx1$ thru/or DxN_c divided into the sub signal of two or more time delay for the operation of a weighting factor to the adaptive control mold controller 7, and carries out the multiplication of the data $Dw1$ thru/or DwN_c of a weighting factor calculated by the adaptive control mold controller 7 to each inputted signal, respectively. The transversal filter circuit 23-1 thru/or the detail configuration of 23- N_c are the same as that of the transversal filter circuit of the time domain signal-processing section 4-1 for TDMA concerning the 1st operation gestalt (refer to drawing 4). Here, in order to distinguish each weighting-factor w by which multiplication is carried out, the serial number 1 of the transversal filter circuit in each above-mentioned sub digital disposal circuit thru/or N_c shall be expressed with the 2nd suffix, and the suffix of weighting-factor w shall express the serial number 1 of the multiplier in each above-mentioned transversal filter circuit thru/or M with the 1st suffix for the sub digital disposal circuit 16-1 the serial number 1 of 16-J thru/or J by the 3rd suffix.

[0025] Moreover, the signal outputted from the delay circuit 21-1 is inputted into a delay circuit 21-2 and the down sampler 22-2, and the down sampler 22-2 carries out the down sampling of the inputted signal with a sampling frequency $1/N_c$ time the sampling frequency [the down sampler 14-1 thru/or] of 14-J, and outputs the signal after processing to an adder 24 through the transversal filter circuit 23-2. Like the following the signal outputted from delay circuit 21- $(nc+1)$ and down sampler 22- ($nc+1$). Down sampler 22- ($nc+1$) carries out the down sampling of the inputted signal with a sampling frequency $1/N_c$ time the sampling frequency [the down sampler 14-1 thru/or] of 14-J. The signal after processing is outputted to an adder 24 through transversal filter circuit 23- ($nc+1$). Furthermore, an adder 24 adds the signal of a two or more N_c (s) individual inputted, and outputs the signal of an addition result to an adder 17.

[0026] The interior is constituted by the sub digital disposal circuit 16-2 thru/or 16-J as well as the sub digital disposal circuit 16-1. two or more [to which an adder 17 is outputted from the sub digital disposal circuit 16-1 thru/or 16-J] -- J signals by which adaptive control was carried out are added, and the signal of an addition result is outputted as processing signal $z(t)$. The time domain signal-processing section 4 compounds the signal data $Dx1$ thru/or DxN_c outputted from the sub digital disposal circuit 16-1 each transversal filter circuit 23-1 of the two or more $J \times N_c$ individual in 16-J thru/or 23- N_c to a signal vector $[Y]$, and outputs it to the adaptive control mold controller 7. Moreover, the time domain signal-processing section 4 decomposes into the weighting-factor data $Dw1$ thru/or DwN_c , and carries out the multiplication of the weighting-factor vector $[W]$ inputted from the adaptive control mold controller 7 to the signal inputted there in each transversal filter circuit 23-2 of a two or more $J \times N_c$ individual thru/or 23- N_c .

[0027] In the control unit of the array antenna constituted as mentioned above The adaptive control mold controller 7 is based on the signal vector $[Y]$ outputted from the time domain signal-processing section 4, and a predetermined study sequence signal. a minimum of [for

example,] — an error signal serves as min using the predetermined adaptive control algorithm using error (MMSE) criteria the 2nd [an average of] power — as — two or more — each weighting factor for the $J \times N \times M$ piece multiplier 26-1 thru/or 26-M is calculated, and it is fed back and set as each multiplier 26-1 thru/or 26-M.

[0028] The adaptive control mold controller 7 outputs the reactance value signal for controlling the directivity of array antenna equipment 100 further. The adaptive control mold controller 7 here For example, the sub signal generated in the time domain signal-processing section 4 before consisting of digital computers, such as a computer, and starting data communication, It is based on the study sequence signal sbp (m) generated with the study sequence signal generator 6. By performing adaptive control processing illustrated by the flow chart of drawing 6 It is characterized by calculating and setting up each variable reactive element 12-1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance values X_1 , —, X_6 of 12-6. The adaptive control mold controller 7 is made to specifically precess each variable reactive element 12-1 thru/or the reactance values X_1 , —, X_6 of 12-6 only for predetermined shift-amount delta X one by one. The gradient vector of the predetermined criterion function (function fh with the study sequence signal sbp in several 68 later mentioned with this operation gestalt (m) by which generating was carried out [above-mentioned] with the sub signal calculated from input-signal y (t)) which makes each reactance value a variable is calculated. Subsequently, the reactance values X_1 , X_2 , —, X_6 are calculated so that the criterion function value concerned may serve as max based on the calculated gradient vector. The reactance value signal which consists of reactance values X_1 , X_2 , —, X_6 is turned and outputted to a variable reactive element 12-1 thru/or 12-6. By it [0029] set up so that the main beam of the above-mentioned array antenna equipment 100 may be turned in the direction of a request wave and null may be turned in the direction of an interference wave Subsequently, the control unit of the array antenna of the operation gestalt concerning this invention and the principle of the control approach are explained.

[0030] The model of the signal which arrives at the antenna array which consists of components of N ($N > 1$) individual which has introduction and P persons' user terminal is considered. the radio signal transmitted from the sending station — touch-down — incidence is carried out by the incident angle (it is also called an arrival angle (Angle of Arrival;AOA).) theta defined in the flat surface containing a conductor 11, and it is received by array antenna equipment 100. With this operation gestalt, the direction of a parasitic element A1 is determined as theta= 0 focusing on a driven element A0. The baseband wave signal sp of the p-th user terminal of the signal transmitted (t) is expressed as follows.

[0031]

[Equation 1]

$$s_p(t) = \sum_{m=-\infty}^{+\infty} s_p(m) \rho_p(t - mT)$$

[0032] Here, sbp (m) shows the m-th information symbol concerning the signal of the p-th user terminal, and rhop (t) expresses an information symbol wave. By the TDMA system, to the signal of each user terminal, information symbol wave rhop (t) has many same things, and is considered as a cosine modulated wave form by which the spread spectrum was carried out. T shows the symbol persistence time or a symbol period. In a CDMA system, a degree type is materialized and this is called the pulse-shape plastic surgery function of the p-th user terminal.

[0033]

[Equation 2]

$$\rho_p(t) = \sum_{j=0}^{N_c-1} c_p(j) \Psi(t - jT_c)$$

($0 \leq t \leq T$)

[0034] It is the {cp (j)}, j= 0, —, diffusion code by which N_c-1 was assigned to the p-th user terminal, T is symbol duration time equal to the product of the chip spacing T_c and the number

N_c of chips per symbol here, and $\psi(t)$ is a chip wave signal which is defined by the time amount section $[0, T_c]$ and which is normalized. Furthermore, when an over sampling technique period is set to Δ , it is $T_c/\Delta = 2$, and when a transmission bit rate is set to f_b , a symbol bit rate is expressed with $2 \times 127 \times f_b$. The diffusion sign sequence may be periodic depending on the specification to adopt, or may be aperiodic. this application description considers the case of being periodic. The array input-signal vector $[x(t)]$ of N dimension received with the array antenna equipment without a noise which consists of an antenna element of N individual is expressed as follows. Hereafter, a vector or a matrix is expressed with $[-]$ in this application description.

[0035]

[Equation 3]

$$[x(t)] = \sum_{p=1}^P \sum_{l=1}^{L_p} [a(\theta_l^p)] \xi_l^p s_p(t - \tau_l^p) \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) [g_p(t - mT)]$$

[0036] Here, several 3 inner N dimension vector $[g_p(t)]$ is called the channel impulse response between space-time of the symbol wave signal between space-time of the p -th user terminal, or symbol level like a degree type.

[0037]

[Equation 4]

$$[g_p(t)] = \sum_{l=1}^{L_p} [a(\theta_l^p)] \xi_l^p \rho_p(t - \tau_l^p)$$

[0038] θ_{lp} , τ_{lp} , and ρ_{lp} express the arrival angle (AOA) corresponding to the l -th path, the time delay, and the propagation loss of a signal of the p -th user terminal, respectively. Furthermore, N dimension vector $[a(\theta)]$ expresses the Ares tearing vector corresponding to θ , and $s_p(m)$ and L_p show the total of the m -th information symbol concerning the signal of the p -th user terminal, and a multi-pass wave, respectively. The following matters are assumed to several 3 component.

<Assumption 1> The signal to receive is the periodic steady state of a wide sense, when sampled the symbol period of fraction spacing (fractionally spaced), and when sampled at a symbol rate, it is the steady state of a wide sense. The signal vector $[x(t)]$ of the periodic steady state of a wide sense is defined by the degree type.

[0039]

[Equation 5] $E\{[x(t_1)][x(t_2)]^H\} = E\{[x(t_1+T)][x(t_2+T)]^H\}$

[0040] Here, $[-]^H$ shows conjugation transposition and $E\{-\}$ shows statistical expected value. the <assumption 2> information symbol $s_p(m)$ and $p = 1, 2, \dots, P$ are independence and the same distribution, and fill a degree type.

[0041]

[Equation 6]

$E\{s_p(m) s_p^*(n)\} = \delta_{m,n}$ [0042] Here, $[-]^*$ shows a complex conjugate and δ and q show a Kronecker's delta function.

the channel $\{g_p(t)\}$ of <assumption 3> plurality, and $p = 1, 2, \dots, P$ between the periods by which 1, 2, \dots , the interest to which P carries out predetermined data communication were held \dots linearity \dots and it is eternal in time and belongs to the persistence time of finite within the time amount section $[0, D_p T]$.

[0043] Next, it formulizes about the model of the signal received especially with array antenna equipment 100. Input-signal $y(t)$ without the noise outputted from array antenna equipment 100 equipped with the driven element A0 which drawing 1 shows and a parasitic element A1 thru/or A6 is specified by the degree type (see the conventional technical reference 3 "Ohira *****, "equivalence wait vector [of an ESUPA antenna] and array factor expression", Institute of Electronics, Information and Communication Engineers technical report, A-P 2000-44, SAT 2000-41, and MW2000-July, 2000 [44 or]").

[0044]

[Equation 7] $y(t)=[i]T[x(t)]$ [0045] Moreover, a steering vector $[a(\theta)]$ is expressed with a degree type.

[0046]

[Equation 8] $[a(\theta)] = (1, \exp(j(2\pi r/\lambda) \cos(\theta)), \dots, \exp(j(2\pi r/\lambda) \cos(\theta - 5 \times 2\pi/6)))^T$ [0047] Here, the diameters of an array are $r=\lambda/4$, λ expresses the wavelength of the radio frequency of a request wave, and the equivalence wait vector $[i]$ considered in the conventional technical reference 3 is drawn like a degree type.

[0048]

[Equation 9] $[i]=C[I+YX]-1[y_0]$ [0049] Here, I is a unit matrix.

[0050]

[Equation 10] $[y_0] = [y_{00}, y_{10}, y_{10}, y_{10}, y_{10}, y_{10}, y_{10}]^T$ — [Equation 11]

$$X = \begin{bmatrix} R_0 & & & & & 0 \\ & jX_1 & & & & \\ & & \ddots & & & \\ 0 & & & jX_6 & & \end{bmatrix}$$

[Equation 12]

$$Y = \begin{bmatrix} y_{00} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} \\ y_{10} & y_{11} & y_{21} & y_{31} & y_{41} & y_{51} & y_{61} \\ y_{10} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} & y_{51} \\ y_{10} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} \\ y_{10} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} \\ y_{10} & y_{51} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} \\ y_{10} & y_{61} & y_{51} & y_{41} & y_{31} & y_{21} & y_{11} \end{bmatrix}$$

[0051] X is a reactance matrix for adjusting the pattern of an antenna, $R_0=50\Omega$ is the input impedance of a radio set, and X_1, \dots, X_6 are parameters outputted as a reactance value signal from the adaptive control mold controller 7. The admittance matrix to which Y expresses the cross coupling between the components of an antenna, and $[y_0]$ are the related admittance vectors, and contain the following [component / the].

[0052] (a) y_{00} expresses the self-input admittance of a driven element A0.(b) y_{10} expresses a driven element A0, a parasitic element A1, or the joint admittance of A6.(c) y_{11} expresses a parasitic element A1 thru/or the self-input admittance of A6.(d) y_{21} expresses the joint admittance of the parasitic element A1 which adjoins mutually, A2 and A2, A3 and A3, A4 and A4, A5 and A5, A6, or A6 and A1.

(e) y_{31} expresses the joint admittance of two parasitic elements A1 located in a line on both sides of one parasitic element in between, A3, A2, A4 and A3, A5 and A4, A6 and A5, A1, or A6 and A2, and (f) y_{41} express two parasitic elements A1 which counter on both sides of a driven element A0, A4, A2 and A5, or the joint admittance of A3 and A6.

[0053] Because of reciprocity and the patrol-symmetric property of array antenna equipment 100, only six components are independent as mentioned above. Moreover, C is a multiplier about the gain of an antenna. When it is array antenna equipment 100 which drawing 1 shows, the value of $C=131.2$ has been acquired from the actual measurement result in approximation. The admittance vector $[y_0]$ and a different input value (entry) to admittance-matrix Y are shown in a table 1.

[0054]

[A table 1]

----- $y_{00}=0.00860035-0.0315844j$ $y_{10}=-$ $0.00372642+0.0072319j$ $y_{11}=0.00962295-0.01656835j$ $y_{21}=-$ $0.000377459+0.0117867j$ $y_{31}=0.00002720885-0.0063736j$ $y_{41}=0.001779525+0.002208335j$ -----

----- [0055] If several 3 is substituted for several 7 and additive noise is taken into consideration, input-signal $y(t)$ outputted from the single port of array

antenna equipment 100 can be expressed like a degree type.

[0056]

[Equation 13]

$$y(t) = [i]^T [x(t)] \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} b_p(m) g_{a_p}(t-mT) + n(t)$$

[0057] Here, the following function contained in several 13 is also called the symbol wave signal between space-time of the p-th user terminal.

[0058]

[Equation 14]

$$g_{a_p}(t) = [i]^T [g_p(t)] \\ = \sum_{l=1}^{L_p} [i]^T [a(\theta_l^p)] \xi_l^p \rho_p(t - \tau_l^p) \\ = \sum_{l=1}^{L_p} f(\theta_l^p) \xi_l^p \rho_p(t - \tau_l^p)$$

[0059] Here, f(theta) expressed with a degree type is the pattern of array antenna equipment 100.

[0060]

[Equation 15] $f(\theta) = f(\theta, X_1, \dots, X_6) = [i]^T [a(\theta)]$

[0061] The impulse response g_p between [of two] space-time (t) and $[g_p(t)]$ have the clearly same persistence time. Additive noise has satisfied the following assumptions.

<Assumption 4> additive noise is a white noise of a zero average with which the following two formulas are filled, and was not correlated with the signal of a user terminal.

[0062]

[Equation 16] $E[n(t)] = 0$ — [Equation 17] $E[n(t)^2] = \sigma^2$ [0063] Here, σ^2 express the power of a noise.

[0064] As for several 9 thru/or several 14, the output signal of array antenna equipment 100 also shows that it is the nonlinear function of reactances X_1, X_2, \dots, X_6 .

[0065] Next, ecad filtering between space-time for removing the signal which is not desirable performed in the time domain signal-processing section 4 is explained. The variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 perform time processing of the control unit of the array antenna when having the set of the given reactance value first using the time domain signal-processing section 4-1 for TDMA illustrated by drawing 3. In the case of TDMA, processing is performed based on a symbol wave signal. A shift register 13-1 thru/or the sampling period in 13- (J-1) are expressed with delta, and let $J=T/\delta$ (J is one or more integers) be the multiplier of over sampling technique. If input-signal $y(t)$ is sampled by assumption A2 by time amount $t=i\delta+mT$ (here, m the integer of arbitration; $i=0, 1, \dots, J-1$), several 13 will become like a degree type.

[0066]

[Equation 18]

$$y(i\delta+mT) \\ = \sum_{p=1}^P \sum_{d=0}^{D_p} b_p(m-d) g_{a_p}(i\delta+dT) + n(i\delta+mT)$$

($i=0, 1, \dots, J-1$)

[0067] The periodic steady state of the signal of the terminal described by the assumption A1 If it uses () [conventional technical reference 4 "L.Tong] et al., "Blind identification and equalization based on second-order statistics : a time domain approach and" IEEE Transaction. Information Theory, Vol.40, pp.340-349, and refer to March 1994." The approach of a multichannel model that the transversal filter circuit 23-1 which is the equalizer of fraction spacing illustrated by drawing 3 thru/or 23-J were extended is easily establishable like a degree type.

[0068]

[Equation 19]

$$[y_b(m)] = \sum_{p=1}^P \sum_{d=0}^{D_p} s_p b_p(m-d) [h_p(d)] + [n_b(m)]$$

[0069] Here, the impulse response vector between [of J dimensions] signal vector [y_b(t)] space-time [h_p(d)] and a noise vector [n_b(m)] are expressed with a degree type.

[0070]

[Equation 20] [y_b(m)] = (y(mT), and [y(mT-delta), ..., y(mT-(J-1)delta)]) T -- [Equation 21]

[h_p(d)] = (gap(dT), and [gap(dT-delta), ..., gap(dT-(J-1)delta)]) T -- [Equation 22] [n_b(m)] = (n

(mT), and [n(mT-delta), ..., n(mT-(J-1)delta)]) T [0071] The dimension of an input signal [y_b(m)] is J each about m, and J is called "the number of over sampling technique channels." About

the limitation of the number of extended channels by over sampling technique, the conventional technical reference 5 (A.J.van der Veen, "Resolution limits of blind multi-user multi-channel identification scheme-the band-limited case", and "in Proceeding of ICASSP'96, Atlanta, GA and May 1996") argues. About the continuation sample in the period of a symbol of M pieces, the following JxM dimension signal vector [Y_T(m)], the symbol vector [S_p(m)] which consists of an information symbol of the M+D_p individual concerning the signal of the p-th user terminal, and a JxM dimension noise vector [N(m)] are formed.

[0072]

[Equation 23] [Y_T(m)] = (y_b(m), and [y_b(m-1), ..., y_b(m-M+1)]) T -- [Equation 24] [S_p(m)] = (s_{bp}(m), and [s_{bp}(m-1), ..., s_{bp}(m-M-D_p+1)]) T -- [Equation 25] [N(m)] = (n_b(m), and [n_b(m-1), ..., n_b(m-M+1)]) T

[0073] next Sylvester (Sylvester) concerning user-terminal p -- if it collapses and the term of impulse response [of the die length (dimension) of x(D_p+1) J of the channel] [[h_p(0)] T, [h_p(1)] T, ..., [h_p(D_p)] T] T defines a matrix, it will become a MJx (M+D_p) degree matrix like a degree type.

[0074]

[Equation 26]

[H_p^(M)]

$$= \begin{bmatrix} [h_p(0)] & \dots & [h_p(D_p)] & 0 & \dots & \dots & 0 \\ 0 & [h_p(0)] & \dots & [h_p(D_p)] & 0 & \dots & 0 \\ \vdots & \ddots & \dots & \ddots & \dots & \ddots & \vdots \\ 0 & \dots & \dots & 0 & [h_p(0)] & \dots & [h_p(D_p)] \end{bmatrix}$$

[0075] Here, "0" expresses zero J-dimensional vector. Several 19 is extensible to a degree type.

[0076]

[Equation 27]

$$[Y_T(m)] = \sum_{p=1}^P [H_p^{(M)}] [S_p(m)] + [N(m)]$$

[0077] Therefore, equalization to the sub signal in the time domain signal-processing section 4-1 for TDMA can be performed by the degree type.

[0078]

[Equation 28] z_T(m)=[W]T[Y_T(m)]

[0079] It is here and is [Equation 29]. [W] = [— w — it is a weighting-factor vector for 1, 0, —, w_{J0}, —, w₁, M-1, — and the transversal filter circuit 23-1 that is the equalizer with which w_J and M-1]T were illustrated by drawing 4. the minimum average square error (MMSE) criteria -- being based -- the optimal weighting factor for the transversal filter circuit 23-1 -- the solution from several 30 -- it is given by the solution of him and the well-known Wiener-hop, several 31 [i.e.,].

[0080]

[Equation 30]

$$\min_{[w]} E |s_{b_1}(m-v) - z_T(m)|^2$$

[Equation 31]

$$[WMMSE]^*=[RT]-1[r(v)]$$

[0081] Here, sb1 (m) is the study sequence signal of the signal of a desired user terminal, and $v \geq 0$ is delay of a study sequence signal required for implementation of causal filtering (causal filtering) in consideration of a time delay v. Adaptive control of the adaptive control mold controller 7 is carried out by calculating a weighting-factor vector [W] so that the error of the signal sb1 (m-v) with which only the predetermined time delay v was delayed in the study sequence signal, and the processing signal zT (m) may serve as min so that clearly from several 30. [RT] and [r (v)] are the correlation vectors between the temporal phase Seki matrix of the signal vector calculated as follows, respectively, a study sequence signal, and a signal vector.

[0082]

$$[Equation 32] [RT]=E\{[YT(m)][YT(m)]^H\}$$

$$[Equation 33] [r(v)]=E\{sb1^*(m-v)[YT(m)]\}$$

[0083] The adaptive control mold controller 7 outputs the weighting-factor vector [W] searched for by several 31 thru/or 33 to the time domain signal-processing section 4, in the multiplier 26-1 of a JxM individual thru/or 26-M, the multiplication of two or more weighting-factor vectors [W] is carried out to a signal vector [YT], the signal of a multiplication result is added with adders 27 and 17, and they are outputted. The adaptive control mold controller 7 makes the residuum power of an output signal zT (k) minimize by repeating above-mentioned processing and completing several 30 error based on the error signal of the Signal zT (k) and the study sequence signal which were outputted. Moreover, the minimum residuum power in case the variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 have the set of the given reactance value is called for like a degree type.

[0084]

[Equation 34]

$$\begin{aligned} \sigma_{T_MMS E}^2(v) \mid_{x_1, \dots, x_6} &= E\{ |b_1(m-v) - z_T(m)|^2 \\ &= E\{ |b_1(m-v)|^2 - [W_{MMS E}]^T [R_T] [W_{MMS E}]^* \\ &= E\{ |b_1(m)|^2 - [r(v)]^H [R_T]^{-1} [r(v)] \} \end{aligned}$$

[0085] Actually, the minimum residuum power of several 34 is the function of the reactance values X_1, \dots, X_6 .

[0086] The variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 explain the case where the time domain signal-processing section 4-2 for CDMA illustrated by drawing 5 next in time domain processing of the control unit of the array antenna when having the set of the given reactance value is used. In the case of CDMA, the time domain processing concerned is performed to pulse-shape plastic surgery functions and those related matched filters 15-1 thru/or the output signal from 15-J. the sampling period in a shift register 13-1 thru/or 13- (J-1) $\Delta = T_c/J$ being shown (over sampling technique multiplier whose J is the natural number) $t = l\Delta - \text{idelta}$ and (la \rightarrow natural number; i \rightarrow if it samples by 0, 1, \dots , J-1), the discrete format of several 13 will become like a degree type.

[0087]

[Equation 35]

$$\begin{aligned} y(l\Delta - i\Delta) \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) g_p(l\Delta - i\Delta - mT) + n(l\Delta - i\Delta) \end{aligned}$$

[0088] If the discretized input signal $y(l\Delta - \text{idelta})$, i = 0, \dots , J-1 are accumulated, a signal vector like a degree type will be acquired.

[0089]

[Equation 36]

$$\begin{aligned} [y_v(l\Delta - i\Delta)] \\ = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) [g_p(l\Delta - mT)] + [n_v(l\Delta - i\Delta)] \end{aligned}$$

[0090] Here, $[y_v(laT_c)]$, $[gvp(laT_c)]$, and $[nv(laT_c)]$ mean as follows a signal vector, the symbol wave signal between space-time, and the J-dimensional vector that shows a noise, respectively.

[0091] [Equation 37] $[y_v(laT_c)] = [y(laT_c), \dots, y(laT_c - (J-1)\delta)]^T$ [Equation 38] $[gvp(laT_c)] = [gap(laT_c), \dots, gap(laT_c - (J-1)\delta)]^T$ [Equation 39] $[nv(laT_c)] = [n(laT_c), \dots, n(laT_c - (J-1)\delta)]^T$ [0092] A degree type is assumed about the chip wave which it normalized.

[0093] [Equation 40] $\psi(kT_c - laT_c) = \delta_{la, k}$ [0094] At this time, the discrete pulse-shape plastic surgery function of the p-th user terminal is shown by the degree type.

[0095] [Equation 41]

$$\begin{aligned} \rho_p(laT_c) &= \sum_{j=0}^{N_c-1} c_p(j) \Psi(laT_c - jT_c) \\ &= \sum_{j=0}^{N_c-1} c_p(j) \delta_{la, j} \\ &= c_p(la) \end{aligned}$$

($0 \leq la \leq N_c - 1$)

[0096] It is [Equation 42] in order to simplify a notation. If $cbp(la) = c_p(N_c - la)$ and $0 \leq la \leq N_c - 1$, a degree type can show the output-signal vector after carrying out back-diffusion of gas of the pulse-shape plastic surgery function of a p0 position user terminal by the matched filter 15-1 thru/or 15-J.

[0097] [Equation 43]

$$\begin{aligned} X_b(laT_c) &= \sum_{i=0}^{N_c-1} [y_v(laT_c - iT_c)] \rho_{p_0}(N_cT_c - iT_c) \\ &= \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) [q v_p^{(p_0)}(laT_c - mT)] + [X b_n^{(p_0)}(laT_c)] \end{aligned}$$

[0098] It is here and is [Equation 44].

$$[q v_p^{(p_0)}(laT_c)] = \sum_{i=0}^{N_c-1} [g v_p(laT_c - iT_c)] c v_{p_0}(i)$$

[Equation 45]

$$[X b_n^{(p_0)}(laT_c)] = \sum_{i=0}^{N_c-1} [n v(laT_c - iT_c)] c b_{p_0}(i)$$

[0099] Like formulation of several 19 vector, laT_c is expressed with $kT - jT_c$ (here, it is $0 \leq j \leq N_c - 1$), and the signal vector of the sub digital disposal circuit 16-1 thru/or the symbol level in 16-Nc is defined like a degree type.

[0100]

[Equation 46] $[X_c(kT)] = [[X_b(kT)]^T, \dots, [X_b(kT - (N_c - 1)T_c)]^T]^T$ [0101] By several 43, a degree type can show several 46.

[0102]

[Equation 47]

$$[X_c(kT)] = \sum_{p=1}^P \sum_{m=-\infty}^{+\infty} s_p(m) [q c_p^{(p_0)}(kT - mT)] + [X c_n^{(p_0)}(kT)]$$

[0103] It is here and is [Equation 48].

$$\begin{aligned} [q c_p^{(p_0)}(kT)] &= [[q v_p^{(p_0)}(kT)]^T, \dots, [q v_p^{(p_0)}(kT - (N_c - 1)T_c)]^T]^T \end{aligned}$$

[Equation 49]

$$[X c_n^{(p_0)}(k T)] \\ = [[X b_n^{(p_0)}(k T)]^T, \dots, [X b_n^{(p_0)}(k T - (N_c - 1) T_c)]^T]^T$$

[0104] From assumption 3, it is the wave signal of a $J \times N_c$ dimension.

[Equation 50]

$$[q c_p^{(p_0)}(k T)]$$

It is known that ***** is restricted. Therefore, several 47 can be expressed like a degree type.

[0105]

[Equation 51]

$$[X c_n^{(p_0)}(k T)] = \sum_{d=0}^{D_{p_0}} s b_{p_0}(k-d) [q c_p^{(p_0)}(d T)] \\ + \sum_{\substack{p=1 \\ p \neq p_0}}^P \sum_{d=0}^{D_p} s b_p(k-d) [q c_p^{(p_0)}(d T)] + [X c_n^{(p_0)}(k T)]$$

[0106] It is here and is [Equation 52].

 D_{p_0}

It is the die length of the symbol level of ** and a p_0 position user-terminal channel. Several 51 shows that the 2nd term contains the cross-correlation component which the signal from the user terminal which is not desirable piled up to the 1st term of the right-hand side including all the components of the signal from a desired user terminal. The above-mentioned cross-correlation component must be oppressed. Based on several 51, ecad processing of symbol level can be performed like a degree type.

[0107]

[Equation 53]

$$z_c(k) = \sum_{b=0}^{M-1} [w_b]^T [X c_n^{(p_0)}(k - (b-1) T)] = [W]^T [Y_c(k)]$$

[0108] Here, the signal vector $[Y_c(k)]$ and weighting-factor vector $[W]$ of a $J \times N_c \times M$ dimension are expressed with a degree type.

[0109]

$$[Equation 54] [Y_c(k)] = [[X c_n(k T)]^T, \dots, [X c_n(k T - (M-1) T)]^T]^T \quad [0110]$$

[Equation 55]

$$[W] = [[w_0]^T, \dots, [w_{M-1}]^T]$$

$$[Equation 56] [w_m] = [w_0 \text{ --- } w_1 \text{ --- } \dots \text{ --- } w_{M-1}]$$

[0111] Several 56 is a weighting factor by which multiplication is carried out to a signal vector $[Y_c(k T)]$, and the weighting-factor vector $[W]$ of several 55 is generated from all those weighting factors. The transversal filter circuit 23-1 thru/or the number M of taps of 23- N_c are the die length [several 57] of the symbol level of a p_0 position user-terminal channel.

 D_{p_0}

It is chosen according to the number of user terminals of the same channel, and performance requirements. Based on MMSE criteria, several 58 [i.e.,], the optimal weighting-factor vector is acquired like several 59 like the processing in the case of TDMA.

[0112]

[Equation 58]

$$\min_{[W]} E |s b_{p_0}(k - v) - z_c(k)|^2$$

[Equation 59]

$$[W_{p0}]^* = [R_C]^{-1} [\gamma_{p0}(v)]$$

[0113] Here, the correlation vector $[\text{gammap0}(v)]$ of the temporal phase Seki matrix $[R_C]$ of a signal vector, and a study sequence signal and a signal vector is expressed with a degree type, respectively.

[0114]

[Equation 60]

$$[R_C] = E\{[Y_C(k)][Y_C(k)]^H\}$$

[Equation 61]

$$[\gamma_{p0}(v)] = E\{s_{p0}^*(k-v) [Y_C(k)]\}$$

[0115] It is here and is [Equation 62].

$$s_{p0}(k)$$

The study sequence signal (study symbol sequence) of a p_0 position user terminal is shown. The error of the signal $s_{p0}(k-v)$ with which only the predetermined time delay v was delayed in the study sequence signal, and the processing signal $z_C(k)$ is minimized, and adaptive control of the adaptive control mold controller 7 is carried out by calculating a weighting-factor vector $[W]$ so that the control device of an array antenna may output the best engine performance so that clearly from several 58. The adaptive control mold controller 7 outputs the weighting-factor vector $[W]$ searched for by several 59 thru/or 61 to the time domain signal-processing section 4, in the transversal filter circuit 23-1 of a $J \times N_c$ individual thru/or 23- N_c , multiplication is carried out to a signal vector $[Y_C]$, the signal of a multiplication result is added in an adder 24, and a weighting-factor vector $[W]$ is outputted from the sub digital disposal circuit 16-1 thru/or 16- N_c . The adaptive control mold controller 7 makes the residuum power of processing signal $z(k)$ outputted minimize by repeating above-mentioned processing and making it converge based on the error signal of the processing signal $z(k)$ and the study sequence signal which are outputted. The minimum residuum power when having the set of a reactance value with which the variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 were given like several 34 is expressed like a degree type.

[0116]

[Equation 63]

$$\begin{aligned} \sigma_{C_MMSE}^2(v) |_{x_1, \dots, x_6} &= E\{s_{p0}(k-v) - z_C(m)\}^2 \\ &= E\{s_{p0}(k-v)\}^2 - [W_{p0}]^T [R_C] [W_{p0}]^* \\ &= E\{s_{p0}(k)\}^2 - [\gamma_{p0}(v)]^H [R_C]^{-1} [\gamma_{p0}(v)] \end{aligned}$$

[0117] As explained above, while the adaptive control mold controller 7 carries out adaptation processing of the request signal in a time domain in the time domain signal-processing section 4, it can process a request signal in a space field in array antenna equipment 100 (space-time concomitant use ecad filtering). The above-mentioned content shows that it may be included [in TDMA] by the approach that both formulation of processing is the same also in CDMA, when the variable reactive element 12-1 of array antenna equipment 100 thru/or 12-6 have the set of a predetermined reactance value. Hereafter, processing signal $z(m)$ expresses the processing output in the case of both TDMA and CDMA, and this is expressed with a degree type.

[0118]

$$[Equation 64] \quad z(m) = [W]^T [Y(m)]$$

[0119] As mentioned above, a signal vector $[Y(m)]$ is the function of a variable reactive element 12-1 thru/or the reactance value of 12-6 again, and ecad filtering which uses together processing between the optimal space-time to the signal of the p -th user terminal is written like minimizing several 65 simultaneously with reference to a weighting-factor vector $[W]$ and the reactance values X_1, X_2, \dots, X_6 , several 66 [i.e.,].

[0120]

[Equation 65]

sigmatotal2=E|sbp(m-v)-z(m)|2 -- [Equation 66]

 $(X h_1, \dots, X h_6, W h)_{opt}$

$$= \arg \min_{x_1, \dots, x_6, [W]} E |s b_p(m-v) - [W]^T [Y(m)]|^2$$

[0121] Under the set of the given data, it is known that the solution method of the optimal weighting-factor vector and reactance value of several 66 is activation of the global retrieval on the associated field. However, it is impossible to use actually the global retrieval which such time amount requires. Therefore, it is necessary to consider a certain alternate method.

[0122] The most fundamental approach also in the optimization approach is the alternative searching method (alternative search) based on a coordinate, and is applied with the result sufficient for many applications. On this application descriptions, several 66 optimization problem is solved using the alternative searching method based on this coordinate.

[0123] Subsequently, the renewal algorithm of a block for performing actually the above-mentioned space-time concomitant use ecad filtering is explained. In the above explanation, the procedure which calculates a weighting-factor vector [W] was explained, having assumed that it had the value to which the variable reactive element 12-1 thru/or the reactance value of 12-6 were given beforehand. The following parts of this application description explain adaptive control processing of the reactance value of the array antenna equipment 100 performed by the adaptive control mold controller 4 based on the flow chart of drawing 6. In the point of the alternative retrieval based on a coordinate, several 66 optimization problem is formulized from two phases of procedures in which views differ. First, it assumes that the reactance values X1, X2, ..., X6 are being fixed as explanation of a general procedure, and the optimal weighting-factor vector is dispelled. This is shown in several 31 or several 59. Therefore, several 66 becomes like a degree type.

[0124]

[Equation 67]

 $(X h_1, \dots, X h_6)_{opt}$

$$= \arg \min_{x_1, \dots, x_6} E |s b_p(m-v) - [W_{opt}]^T [Y(m)]|^2$$

$$= \arg \min_{x_1, \dots, x_6} \{ E |s b_p(m)|^2 - [r(v)]^H [R]^{-1} [r(v)] \}$$

$$= \arg \min_{x_1, \dots, x_6} \{ \sigma_p^2 - [r(v)]^H [R]^{-1} [r(v)] \}$$

[0125] It is here and is [Equation 68]. $[Wopt]^* = [R]^{-1} [r(v)]$

[Equation 69] $[R] = E[[Y(m)][Y(m)]^H]$

[Equation 70]

 $[r(v)] = E[sb_p(m-v)[Y(m)]]$

[0126] The time delay v of a study sequence signal is beforehand determined by the adaptive control mold controller 7 so that the error of the study sequence signal with which only time amount v was delayed, and processing signal z(t) may be minimized based on several 30 and several 58 criteria. Moreover, a degree type is the power of the symbol signal of the p-th user terminal.

[0127]

[Equation 71] $\text{sigmap}2 = E |sbp(m)|^2$ [0128] Subsequently, the procedure of the renewal of a block which solves an optimization problem is explained more concretely. The optimal reactance value is looked for according to the die length to which received data were restricted, and several 67, and the correlation vector $[r(v)]$ of the temporal phase Seki matrix [R] of a signal vector, and a study sequence signal and a signal vector is presumed by it. That is, the following two operations are performed.

[0129]

[Equation 72]

$$[R \ h] = \frac{1}{N_t} \sum_{m=m_k}^{m_k+N_t-1} [Y \ (m)] [Y \ (m)]^H \Big|_{x_1, \dots, x_6}$$

[Equation 73]

$$[r \ h \ (v)] = \frac{1}{N_t} \sum_{m=m_k}^{m_k+N_t-1} s \ b_p^*(m-v) [Y \ (m)] \Big|_{x_1, \dots, x_6}$$

[0130] here — $m_k=N_t l$ and $l=$ — it is 0, 1, —, M_t and M_t shows the number of data blocks required for convergence. Under the set of the given reactance value, the number N_t of symbols is chosen by the activity of the 2nd [an average of] power (LMS) algorithm of the minimum so that it can be completed as a steady state by the weighting-factor vector $[W]$ within the symbol period of N_t individual. A formula, such as relating to several 7, several 9, several 13, several 26, several 54, and these, shows that a signal vector $[Y \ (m)]$ is not the function with which the reactance values X_1, X_2, \dots, X_6 were expressed explicitly. that is, the term $[r \ (v)] [R] \ H$ of the secondary format of a correlation vector — it means that $-1 [r \ (v)]$ is the implicit function of the reactance values X_1, X_2, \dots, X_6 .

[0131] the term $[r \ (v)] [R] \ H$ an updating algorithm suitable in order to discover the optimal reactance ($X_{h1}, X_{h2}, \dots, X_{h6}$) opt to an implicit function is the maximum dive algorithm for updating a reactance, and concerning the reactance values X_1, X_2, \dots, X_6 — the gradient vector of $-1 [r \ (v)]$ must be evaluated. Term $[r \ (v)] [R] \ H$ — since $-1 [r \ (v)]$ is evaluated according to the given data block to which die length was limited — the renewal algorithm of a block — Term $[r \ (v)] [R] \ H$ — it is constituted about the estimate based on the data block of $-1 [r \ (v)]$. A degree type is assumed as a criterion function.

[0132]

[Equation 74]

$$[f \ h \ (X_1, X_2, \dots, X_6)] \\ = \sigma_{h_p}^2 - [r \ h \ (v)]^H [R \ h]^{-1} [r \ h \ (v)] \Big|_{x_1, \dots, x_6}$$

[0133] Here, the 2nd term of the right-hand side makes a variable the reactance values X_1, \dots, X_6 . $\sigma_{h_p}^2$ is the power by which the symbol signal of the p -th user terminal was evaluated. In the context of the maximum dive algorithm (see the conventional technical reference 6 "R.A.Monzingo et al., "Introduction to Adaptive Arrays", John Wiley & Sons, Inc., and 1980"), the following updating equations for performing adaptive control processing to a reactance value are obtained from several 74.

[0134]

[Equation 75]

$$X \ v^{(k+1)} = X \ v^{(k)} - \alpha \nabla_{X \ v} f \ h \ (X \ v) \Big|_{X \ v = X \ v^{(k)}}$$

[0135] It is here and is [Equation 76]. $X \ v = [X_1, X_2, \dots, X_6]^T$ — [Equation 77] $X \ v(k) = [X_1(k), X_2(k), \dots, X_6(k)]^T$ [0136]

[Equation 78]

$$\nabla_{X \ v} f \ h \ (X \ v) = [\nabla_{X_1} f \ h \ (X_1, \dots, X_6), \dots, \nabla_{X_6} f \ h \ (X_1, \dots, X_6)]^T$$

[Equation 79]

$$\nabla_{X_i} f \ h \ (X_1, \dots, X_i, \dots, X_6) \\ \approx [f \ h \ (X_1, \dots, X_i + \Delta X, \dots, X_6) - f \ h \ (X_1, \dots, X_i, \dots, X_6)] / \Delta X$$

[0137] Here, α is a step size for updating, for example, takes the value of 1000 thru/or 2000.

[0138] The procedure of renewal of the reactance value by the adaptive control processing illustrated by drawing 6 is performed as follows. In step S1, the number epsilon which controls the number of occurrence of renewal of a reactance value is set up, and the count k of updating of a reactance is further set to 0 as an initial state. Next, in step S2, initial value [of a reactance value vector] $X \ v \ (0) = (X_1 \ (0), X_2 \ (0), \dots, X_6 \ (0))$ is set up, and subsequently, in step S3, the reactance value signal corresponding to the reactance value vector $X \ v \ (k)$ is generated, and it is

outputted and set as a variable reactive element 12-1 thru/or 12-6. For example, the initial value of a reactance value vector can be set as zero vector, and an updating algorithm can be started from an omnidirectional beam pattern (see drawing 9). And in step S4, based on an input-signal vector $[Y(m)]$ and the study sequence signal vector $sbp(m)$, a matrix of correlation $[R]$ and a correlation vector $[r(v)]$ are calculated, the optimal weight vector $[W_{opt}]$ is calculated using several 68 using several 72 and several 73, and it outputs to the time domain signal-processing section 4. Subsequently, in step S5, the inclination of a criterion function fh is calculated using several 78 and several 79, and the reactance value vector $X_v(k+1)$ is further calculated from the reactance value vector $X_v(k)$ by several 75. Subsequently, in step S6, it is determined whether the inequality of a degree type is materialized.

[0139]

[Equation 80]

$|fh(X_v(k)) - fh(X_v(k+1))| \leq \epsilon$ [0140] Here, ϵ is a repetitive threshold, when several 80 inequality is materialized in step S6, while progressing to step S8, when not materialized, it progresses to step S7, only 1 increments k , and (NO) returns to step S3. In step S8, the reactance value signal corresponding to the reactance value vector $X_v(k+1)$ is generated, it is outputted and set as a variable reactive element 12-1 thru/or 12-6, and adaptive control processing is ended.

[0141] If ecad filtering between space-time based on the ESUPA antenna explained above is used, the steering of the beam of array antenna equipment 100 can be carried out in the arrival direction of a request signal, a spatial interference can be oppressed, and a time interference of ISI contained by the time domain signal-processing section 4 in an input signal can be oppressed.

[Translation done.]

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EXAMPLE

[Example] this invention persons performed computer simulation about the control unit of the array antenna of drawing 1 , and confirmed the effectiveness of ead filtering between space-time by using the control unit of this array antenna. In this simulation, it is a premises network system, and the signal of the DS-CDMA user terminal of the 15 same channels exists, and let a user 1 be a request user. The code die length of the signal of all user terminals is set as 127. The Gaussian distribution of AOA of the path of the signal of each user terminal set up so that the signal of each user terminal might have six multi-pass waves and an include angle might have spacing of 8 times mutually is carried out, and those time delay assumes that it is a thing according to the exponential distribution which have the delay which spread 1.1 symbol period. The propagation loss of a multi-pass wave shall be included by SNR of the array component of the direct wave of the signal of a user terminal. In this case, SNR to the signal of a user's 1 terminal is assumed to be -10dB, and SNR of the signal of all other user terminals changes at random by -26.55dB thru/or -4.76dB. Moreover, all user terminals shall be uniformly distributed in the visual field of array antenna equipment 100. A table 2 has indicated the detailed parameter of the signal a user's 1 terminal.

[0143]

[A table 2]

----- Path theta (degree) tau (symbol) xi (propagation loss)

----- 1 12.30 0 - 0.9669+0.2550j2 21.50 0.04 0.7437-
0.3081j3 20.20 0.05 - 0.5206-0.5100j4 8.70 0.12 - 0.3081-0.4569j5 23.40 0.33 -0.1806+0.3931j6
13.20 0.47-0.1912+0.1275j ----- [0144] Here, the over

sampling technique multiplier was set up with $J=1$, and the number of taps of a transversal filter circuit is set up with $M=1$. As mentioned above, a variable reactive element 12-1 thru/or 12-6 are [Equation 81]. When it has the set of a given reactance value like $X_v = [-53, -136, 61, 51 \text{ and } 59, -146]$ T, N_t is the measurement size of symbol level and can converge the weighting-factor vector of several 64 to the steady state of several 68 with the conventional LMS algorithm based on this.

[0145] Drawing 7 is a graph showing an example of the convergence curve of the residuum power for determining the measurement size N_t of the symbol level converged on a steady state in adaptive control processing of drawing 6 . It turns out that a weighting-factor vector is converged to the steady state within the symbol period of about 200 so that clearly from drawing 7 . This means that number $N_t=200$ of a symbol period are employable. Repeatedly [of the reactance of this simulation], $N_t=200$ are adopted as the number of symbol periods. In order to show the behavior in the case of convergence of an updating algorithm, data block number $M_t=7 \times 20$ and the repetitive threshold $\epsilon = 1 \times 10^{-10}$ of several 81 sake are set up.

[0146] drawing 8 -- drawing 6 -- adaptive control -- processing -- setting -- a data block -- updating -- a sake -- a criterion function -- a value -- convergence -- a curve -- an example -- being shown -- a graph -- it is -- drawing 9 -- drawing 6 -- adaptive control -- processing -- having performed -- the time -- a reactance -- a value -- a vector -- initial value -- X_v -- (- zero --) -- = (0, 0, 0, 0, 0, 0) -- corresponding -- an array antenna -- equipment -- 100 -- a

beam — a pattern — a graph — it is . It starts from the initial value X_v of this reactance value vector (0), adaptive control processing of drawing 6 is performed and updated, and a beam pattern in case the counts k of updating are 2 times, 4 times, 9 times, 13 times, and 19 times, respectively is shown in drawing 10 thru/or drawing 14 . All the multi-pass waves of the signal of a desired user terminal are included with a steady state pattern, and are strengthened, and it turns out that the multi-pass wave of the signal of the user terminal which is not desirable is mitigated with the lower order lobe of a steady state pattern so that clearly from a table 2 and drawing 14 . It is clear from these two drawings by carrying out beam pattern formation of array antenna equipment 100, and time equalization of the input signal in the time domain signal-processing section collectively that ecad filtering between space-time is effectively realizable.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the block diagram showing the configuration of the control device of the array antenna of the operation gestalt concerning this invention.

[Drawing 2] It is the sectional view of the array antenna equipment 100 of drawing 1 .

[Drawing 3] It is the 1st operation gestalt of the time domain signal-processing section 4 of drawing 1 , and is the block diagram showing the configuration of the time domain signal-processing section 4-1 for TDMA.

[Drawing 4] It is the block diagram showing the configuration of the transversal filter circuit 23-1 of drawing 3 .

[Drawing 5] It is the 2nd operation gestalt of the time domain signal-processing section 4 of drawing 1 , and is the block diagram showing the configuration of the time domain signal-processing section 4-2 for CDMA.

[Drawing 6] It is a flow chart explaining the adaptive control processing performed by the adaptive control mold controller 7 of drawing 1 .

[Drawing 7] In adaptive control processing of drawing 6 , it is a graph showing an example of the convergence curve of the residuum power for determining the measurement size N_t of the symbol level converged on a steady state.

[Drawing 8] In adaptive control processing of drawing 6 , it is the graph which shows an example of the convergence curve of the criterion function value for renewal of a data block.

[Drawing 9] It is the graph of the beam pattern of the array antenna equipment 100 corresponding to initial value [of a reactance value vector] $X_v(0) = (0, 0, 0, 0, 0, 0)$ when performing adaptive control processing of drawing 6 .

[Drawing 10] Adaptive control processing of drawing 6 is performed and it is the graph of the beam pattern of array antenna equipment 100 in case the count of updating of a reactance value is 2 times.

[Drawing 11] Adaptive control processing of drawing 6 is performed and it is the graph of the beam pattern of array antenna equipment 100 in case the count of updating of a reactance value is 4 times.

[Drawing 12] Adaptive control processing of drawing 6 is performed and it is the graph of the beam pattern of array antenna equipment 100 in case the count of updating of a reactance value is 9 times.

[Drawing 13] Adaptive control processing of drawing 6 is performed and it is the graph of the beam pattern of array antenna equipment 100 in case the count of updating of a reactance value is 13 times.

[Drawing 14] Adaptive control processing of drawing 6 is performed and it is the graph of the beam pattern of array antenna equipment 100 in case the count of updating of a reactance value is 19 times.

[Description of Notations]

A0 — Driven element,

A1 thru/or A6 — Parasitic element,

1 — Low noise amplifier,

2 — Down converter,
3 — A/D converter
4 — Time domain signal-processing section,
4-1 — The time domain signal-processing section for TDMA,
4-2 — The time domain signal-processing section for CDMA,
6 — Study sequence signal generator,
7 — Adaptive control mold controller,
9 — Coaxial cable
11 — touch-down — a conductor,
12-1 thru/or 12-6 — Variable reactive element
13-1 thru/or 13 -(J-1)— Shift register,
14-1 thru/or 14-J, 22-1, or 22-Nc — Down sampler,
15-1 thru/or 15-J — Matched filter,
16-1 thru/or 16-J — Sub digital disposal circuit,
17, 24, 27 — Adder,
23-1 thru/or 23-J, 23-1, or 23-Nc — Transversal filter circuit,
21-1 thru/or 21- (Nc-1), 25-1, or 25 -(M-1)— Delay circuit,
26-1 thru/or 26-M — Multiplier,
100 — Array antenna equipment.

[Translation done.]

